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FINAL REPORT

FEEDING WHOLE GRAIN AND HIGH GRAIN DIETS TO BROILER CHICKENS AND TURKEYS

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FEEDING WHOLE GRAIN AND HIGH GRAIN DIETS TO BROILER CHICKENS AND TURKEYS

PROJECT 94000208

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FEEDING WHOLE GRAIN AND HIGH GRAIN DIETS TO BROILER CHICKENS AND TURKEYS

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ABSTRACT

Feeding whole grain to meat chickens and turkeys, and laying hens has been suggested to reduce feed processing and transportation costs and improve the net return to poultry producers. Therefore extensive studies were undertaken to examine issues related to this topic with particular emphasis on establishing at what ages and levels whole wheat and barley should be fed and the degree to which current diets can be diluted by whole grain. The results indicate that poultry can utilise whole grain effectively if whole grain is introduced gradually so as to stimulate gizzard development, and does not exceed limits of approximately 30% in broilers and 50% in older turkeys kept to larger weights. Older birds are more able to utilise high levels of whole grain as indicated by no loss of performance by laying hens fed 50% whole wheat and equivalent feed efficiency in older turkeys fed whole grain in contrast to ground grain. It may be economical to feed higher levels of whole grain to young birds despite reduced performance because of decreased feed costs and in some cases improved bird health. Feeding whole grain did not affect carcass meat yield with the only major impact being the increase in gizzard size. Feeding whole grain was most beneficial when fed with a pelleted rather than a mash supplement. Dilution of diets with whole grain reduces nutrient intake and generally was associated with reduced performance. This effect was particularly marked in turkeys where growth, feed efficiency and breast meat yield were dramatically affected. The effect was less dramatic in broilers and suggests that the lower level of breast meat muscling in broilers and/or over-formulation of broiler diets may have played a role in these results. Supplementing essential amino acids to diluted diets partially negated their impact. This confirms existing nutritional principles and clearly illustrates the need to achieve required nutrient intake levels when feeding whole grain. Micronizing whole grain improved its nutritional value but is likely not an economical option for feeding poultry. Both whole barley and wheat can be used in poultry feeding but the results suggest that wheat works slightly better.

In conclusion, this research indicates that whole grain feeding is a viable alternative for poultry producers in Saskatchewan. Even at relatively high levels of whole grain, the effect on bird performance is minimal as long as nutrients in the feed are not excessively diluted.

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FEEDING WHOLE GRAIN AND HIGH GRAIN DIETS TO BROILER CHICKENS AND TURKEYS

AGRICULTURAL DEVELOPMENT FUND
PROJECT 94000208

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WHOLE GRAIN AND HIGH GRAIN DIETS FOR BROILER CHICKENS, LEGHORNS AND COMMERCIAL TURKEYS

INTRODUCTION

In the last several years, some integrated poultry companies in the United Kingdom and the Netherlands have diluted broiler rations with up to 20% whole wheat, and less commonly, turkey feed with up to 40% whole wheat. The claim is that feed processing and ingredient costs have been reduced with little or no effect on performance. Broiler and turkey producers in Western Canada are now attempting to add whole grain to commercial diets but the approach has not been consistent or based on sound nutritional research. Some broiler producers in Western Canada have fed a starter feed for the entire flock but have diluted it with up to 50% whole wheat by 30 days of age. Others have remained on the traditional starter, grower and finisher rations but have diluted with up to 25% whole wheat in the finisher ration.

Poultry producers who have fed whole grain have made two major changes in their feed:

1) They have changed the feed form by supplying some of the grain to the birds as whole kernels instead of as mash or pellets.

2) They have diluted many of the nutrients in the feed by adding grain on top of the feed that they have purchased.

This paper discusses both of these aspects of whole grain feeding but treats them as separate issues. In the research conducted at the University of Saskatchewan, it was found that the response to feed form (pellets, mash or whole grain) was the same regardless of level of feed formulation. Birds also responded similarly to dilution regardless of whether the extra grain was added in whole or pelleted form.

The research studied the effect of whole grain feeding on the growth rate, feed efficiency, mortality, meat yield and digestive tract development of broiler chickens and commercial turkeys. The egg production, feed efficiency, mortality and shell quality of laying hens fed whole grain was also determined. Whole barley was tested with broiler chickens and turkey toms to investigate whether it could fed in situations where it was more economical to use barley based rations than wheat based rations. Dilution of broiler chicken and commercial turkey diets with wheat was investigated to determine the effect on live bird performance and meat yield.

FEED FORM: WHOLE GRAIN, MASH OR PELLETS?

The various degrees of processing of cereal grain tested at the University of Saskatchewan ranged from whole grain to mash grain to pelleted grain. The steam pelleted diets were fed as crumbles or pellets, the crumbles being pellets that had been broken into smaller pieces to feed to young birds. Only conventional steam pelleting will be discussed in this paper although micronized grain was also fed in some trials.

A. Response to Whole Grain Feeding

1) Body Weight Gain and Feed:Gain

Whole grain feeding relies on the bird's gizzard to do the grinding that in the commercial poultry industry is normally done by a hammer mill or roller mill. The bird reacts to the work load of grinding whole grain by developing a larger gizzard but this response is not instantaneous. Unlike depositing fat or breast tissue, significant growth in gizzard muscle mass only occurs when it is forced to exercise by increased levels of whole grain. In the first 6 weeks of age, the gizzard grows progressively larger each time that the amount of whole grain in the ration is increased (Table 1).

Table 1. Gizzard weight[1], with and without digesta contents, of 6 week old broiler cockerels feed pellet based diets with different levels of whole wheat[2]

	Cumulative whole wheat in the feed, %[3]						
	0%	11%	17%	21%	28%	43%	56%
With digesta	100%	131%	139%	142%	143%	146%	154%
Minus digesta[3]	100%	121%	130%	134%	131%	138%	146%

[1] Gizzard weight, as % of controls fed no whole grain.
[2] Average of two trials.
[3] In both trials, the level of whole wheat in the feed was steadily increased as the birds grew older. The cumulative whole wheat intake is an average for the first 6 weeks of age.
[4] Koalin layer was not removed from the gizzards when they were cleaned of digesta contents.

When chickens and turkeys are introduced to feed containing high levels of whole grain, a period of several weeks is needed for the birds to build the gizzard muscle mass necessary to grind it efficiently. In one trial, for example, gizzard weight was measured at 18 and 32 days of age in turkeys introduced slowly or rapidly to whole barley. Turkeys fed 5% to 20% whole grain in the Prestarter showed no stimulation of gizzard size at 18 days of age compared to birds fed just crumbles. When these birds were then fed 35% to 50% whole barley at 19 days of age, their growth slowed because their small gizzards had difficulty processing high levels of whole grain. By 32 days of age, the birds had responded to the whole grain and had gizzards 30% larger than those fed just crumbles. A similar pattern of slowed growth was observed in turkeys switched from low to high levels of whole grain at 40 days of age. Because time is required to develop gizzard muscle mass, some loss in performance occurs as the birds adjust to whole grain and this adjustment period occurs regardless of the age that the birds are first exposed to whole grain.

In Table 2, the body weight gain and feed conversion response is summarized for chickens and turkeys fed different levels of whole grain at young ages. Only small declines in growth rate were observed when feeding up to 20% whole grain, indicating that birds were born with adequate gizzard muscle mass to handle low levels of whole wheat or barley. Feeding above 20% whole grain substantially decreased body weight gain, a drop corresponding to the level at which the birds had to markedly increase gizzard muscle mass to grind the

grain. The slower growth was most noticeable with turkeys fed whole barley. Compared to the effect on body weight gain, feed:gain ratio increased more steadily as more whole grain was fed. For both types of bird and grain, the relationship between feed:gain and level of whole grain was very consistent and feed:gain was increased by 0.65% for each 10% whole grain fed.

TABLE 2. Early body weight gain and feed:gain response of chickens and turkeys fed different levels of whole grain compared to birds fed just crumbles/pellets[1]

Whole grain, %[3]	Relative performance[2]	
	Weight gain	Feed:gain
0 %	100.0 %	100.0 %
5 %	98.9 %	100.9 %
20 %	99.5 %	102.3 %
35 %	97.0 %	102.5 %
50 %	97.0 %	103.6 %
65 %	95.6 %	104.3 %

Relative Gain = 99.72% - 0.09% * Whole Grain %
Relative Feed:Gain = 100.389% + 0.065% * Whole Grain %

[1] Results from the first 6 weeks of whole grain feeding in two chicken and turkey whole wheat feeding trials and one chicken and turkey whole barley feeding trial.
[2] All results expressed as a percentage of treatments with no whole grain. A relative gain less than 100% indicates slower growth compared to the controls while a relative feed:gain over 100% indicates less efficient feed conversion.
[3] The percent of whole grain is not a cumulative number for the first 6 weeks of whole grain feeding but instead applies to an actual level of whole grain fed at some point during the first 6 weeks. The relative performance applies to the week or weeks when that level of whole grain was fed and is not cumulative performance during the first 6 weeks.

After being fed high levels of whole grain for 3 or 4 weeks, both chickens and turkeys could utilize the whole grain as efficiently as grain that had been steam pelleted. In one trial, turkey toms fed 50% whole barley had a body weight gain and feed:gain ratio virtually identical to birds fed just whole pellets once the toms had adjusted to the whole grain (Table 3). The apparent metabolizable energy derived by 10-week-old turkeys from whole wheat and barley was found to be the same as for pelleted wheat and barley. Laying hens fed 50% whole wheat had identical production and feed efficiency over 6 months of lay to birds fed mash or pelleted wheat (Table 4). Once their gizzards develop, chickens and turkeys make effective use of whole grain rations.

TABLE 3. Performance of turkeys fed 50% whole barley relative to 100% pellets

Age fed 50% whole barley	Performance relative to birds fed just pellets	
	Gain	Feed:gain[1]
40 - 68 days[2]	95.8%	100.9%
68 - 96 days[3]	99.3%	99.7%

[1] A feed:gain > 100% is less efficient than pellets.
[2] Birds were fed 20% or more whole barley prior to being fed 50% whole barley from 40 to 68 days of age.
[3] Birds had been given at least 28 days to adjust to 50% whole barley prior to measuring their performance from 68 to 96 days of age.

TABLE 4. Performance of laying hens fed 0% to 50% whole wheat

Level of whole wheat	Egg production		Feed efficiency		Egg weight, g
	Hen day %	Hen housed %	kg/dozen	kg feed / kg egg mass	
0 %	86.2%	84.8%	1.74	2.74	54.5
50 %	86.2%	84.9%	1.75	2.73	54.9

Note: Results averaged for treatments fed mash or pelleted supplements

2) Mortality

Birds fed whole grain generally had lower mortality than birds fed steam pelleted diets, mostly due to a reduction in leg and skeletal problems (Table 5). In one broiler chicken and one turkey tom trial, statistically significant reductions in leg/skeletal problems were observed. The largest improvement in skeletal health occurred in treatments where early growth rate was slowed by feeding high levels of whole grain, with fewer valgus varus leg deformities being the most noticeable benefit (Table 6). The greatest improvement in skeletal health in any of the trials conducted was observed in turkey toms fed whole barley which coincidentally had the greatest decline in early growth of the birds fed whole grain. Even when early growth was unaffected by feeding whole grain, some reduction in leg and skeletal problems was observed.

3) Carcass Yield, Meat Yield and Digestive Tract Development

The eviscerated weight as a percentage of live bird weight (carcass yield) was virtually identical for birds fed no whole grain or high levels of whole grain. The yield normally varied only 0.3% in favour or against whole grain feeding depending on the research trial, with breast meat yield and percentage of abdominal fat being unaffected by whole grain feeding. The only consistent change in carcass yield was associated with the 20 to 30 gram increase in gizzard weight when whole grain was fed. The gizzard was the only organ in the gastrointestinal tract noticeably affected by whole grain feeding, with the weight of the crop, proventriculus and small intestine being the same regardless of feed form. The pH of the gizzard and duodenal contents was sometimes lowered by feeding whole grain but gut viscosity was not altered.

TABLE 5. Summary of leg/skeletal problems and total mortality in broiler chicken and turkey trials feeding whole grain[1]

Treatment comparison[2]	Leg/skeletal problems, %		Total mortality, %	
	No whole grain	Whole grain	No whole grain	Whole grain
Broiler chickens				
1	2.0	1.5	7.5	8.2
2	2.7	0.6	9.6	8.3
3	3.7	1.8	8.5	7.1
4	0.5	0.2	7.1	5.9
5	0.5	0.8	4.9	5.3
Average	1.9	1.0	7.5	7.0
Turkey toms				
1	6.9	3.6	8.9	6.2
2	8.5	4.8	12.1	6.1
3	5.2	5.4	11.8	12.4
4	9.7	6.3	17	9.1
5	9.1	5.7	12.5	11.4
Average	7.9	5.2	12.5	9.0
All birds				
Average	4.9	3.1	10.0	8.0

[1] Summary includes whole wheat and whole barley trials.
[2] The 10 pair wise comparisons were obtained from data from 3 chicken and 3 turkey trials. For each comparison, the feed in the treatments compared had the same nutrient specifications, ingredient composition, supplement form and grit level; the only difference was whether some of the grain was added as whole kernels.

TABLE 6. Effect of whole grain feeding on leg and skeletal problems in broiler chickens and turkey toms[1] with different rates of early body weight gain[2]

	Same early growth in control and whole grain birds[3]		Slower early growth in whole grain birds[4]	
	Valgus varus leg deformity	Total leg/skeletal problems	Valgus varus leg deformity	Total leg/skeletal problems
Mortality/Culls, % of birds placed				
No Whole Grain (Controls)	1.5%	4.5%	2.4%	3.8%
Whole Grain Fed Birds	1.0%	3.0%	1.1%	1.9%
Reduction due to Whole Grain Feeding	0.5%	1.5%	1.3%	1.9%

[1] Combined results for trials using whole wheat or whole barley compared to pellet or mash fed controls.
[2] Depending on the trial, early weight gain was determined at 2 to 3 weeks of age.
[3] Based on 8 pair wise treatment comparisons of birds fed diets with/without whole grain in 3 broiler chicken and 3 turkey tom trials. Early growth of whole grain fed birds in each comparison was within 2% of controls.
[4] Based on 5 pair wise treatment comparisons of birds fed diets with/without whole grain in 2 broiler chicken and 1 turkey tom trial. Whole grain birds in each comparison grew at least 2% slower than the control birds. On average, the whole grain birds in these comparisons grew 4% slower in the first 2 to 3 weeks of age.

4) Economics of Feeding Whole Grain

Worksheets have been produced to help calculate the effect of different whole grain feeding programs on broiler chicken and turkey performance. The economics will be influenced by many factors including:

a. Local grain supply and whether grain is grown on-farm, purchased from neighbors or purchased from an elevator
b. Price and quality of wheat or barley purchased on-farm compared to a commercial mill.
c. Trucking distance to the feed mill.
d. Milling costs for adding grain on-farm versus at a commercial mill.
e. Competitiveness of corn based rations.

Because the influence of whole grain combined with balanced supplements has now been documented, the economics of feeding whole grain in different situations can be calculated.

B. Response to Mash Feeding

Mash feed is 40% fine powder and work by previous researchers shows that this level of

fines will slow broiler growth. By contrast, a good quality pellet may only contained 5% fines while crumbled or rolled feed will contain about 15% fine particles. Young birds especially do not like to eat fines and early growth rate is slowed with mash feed. In the field, broilers fed mash often have 3 week body weights 10% to 20% lower than birds fed crumbles, although many producers find that their birds start to catch up in body weight as they grow older.

Our results with broiler chickens tended to confirm these results (Table 7). Feeding wheat and barley based mash diets dramatically reduced early growth rate but weight gain at later ages was the same as for birds fed pellets. Feed efficiency was relatively unaffected feeding mash, suggesting that the slower early growth was more likely due to lower feed intake than poor digestibility of the mash feed. The reduced early feed intake of the fine mash feed explained much of the difference between mash and steam pelleted rations.

TABLE 7. Performance of broiler chickens fed mash supplements relative to pelleted supplement[1]

Age	Gain	Feed:Gain[2]
0 to 7 days	90.3%	100.6%
7 to 14 days	93.2%	100.8%
14 to 28 days	93.3%	102.1%
28 to 42 days	96.8%	99.3%
42 to 49 days	99.8%	98.7%

[1] Average results from wheat and barley mash trials
[2] Feed:gain was mortality corrected. A feed:gain > 100% is less efficient than pellets.

At early ages, including whole wheat or barley in a mash based diet had a limited effect on growth rate (Table 8). Chickens appeared to consume complete mash diets or mash diets with low to moderate levels of whole grain at approximately the same rate. The decline in growth rate at higher levels of whole grain was less noticeable with mash than pellet based rations. The feed:gain on mash diets increased 0.78% for every 10% whole grain used in the feed, very similar to the 0.65% increase observed for pelleted diets. The gizzard of a young bird could not grind the grain as efficiently as a hammer mill used to produce a mash or pelleted diet at a commercial feed mill.

TABLE 9. Relative gain of broiler chickens fed different levels of whole grain combined with mash or pelleted supplements[1] (first 6 weeks of whole grain feeding)

Whole grain[2], %	Type of supplement	
	Pelleted	Mash
0 %	100.0 %	100.0 %
5 %	99.3 %	100.5 %
20 %	97.8 %	97.0 %
35 %	97.4 %	99.0 %
50 %	96.8 %	98.6 %
65 %	94.8 %	96.9 %

Relative Gain with Pellets = 99.73% - 0.07% * Whole Grain %
Relative Gain with Mash = 100.00% - 0.04% * Whole Grain %

[1] All results expressed as a percentage of treatments with no whole grain. All birds fed whole grain and pelleted supplement compared to birds fed just pellets while those fed whole grain and mash supplements were compared to birds fed just mash.
[2] Performance based on time period when a given level of whole grain was fed.

DILUTION OF CHICKEN AND TURKEY RATIONS WITH WHEAT

Dilution of broiler chicken and commercial turkey rations with whole or pelleted wheat produced similar results. Dilution with whole wheat did not offer any nutritional advantage over adding extra wheat to the pellet. In fact, diluting the rations of young birds with whole wheat produced a slightly greater decline in growth and increase in feed:gain than diluting with pelleted wheat because the birds needed to adjust to the whole grain as well as the dilution of the nutrients in the feed. In nutritional terms, the dilution of the feed with wheat basically produced diets with lower levels of protein and amino acids and the underlying economics of these diets depended on how chickens and turkeys responded to this change in formulation. In most of the trials conducted, only the protein meals and synthetic amino acids were diluted and the level of the vitamins, minerals and medications was maintained at normal levels in the diluted and undiluted rations. This practice helped simplify interpretation of how the birds responded to the feed with above normal amounts of wheat added.

A. Response of Turkey Toms to Wheat Dilution

Turkeys have been bred to produce large amounts of breast muscle and have a very high demand for protein and amino acids such as lysine to support the growth of this tissue. As the birds approach market weight, breast meat accounts for approximately 30% of their live body weight gain, increasing so quickly that the breast meat as a percentage of live and eviscerated carcass weight increases steadily. The rapid increase in breast meat on the carcass is responsible for the increase in the eviscerated carcass yield of turkeys as they grow older.

Because of their rapid growth in lean muscle mass, adding extra wheat to the diet and

lowering the protein and amino acids levels has a detrimental effect on the live performance and carcass characteristics of turkeys. Table 10 displays the effect of replacing with wheat some of the soybean meal and synthetic amino acids in turkey rations formulated to NRC (1994) specifications. As expected, live weight and carcass yield declined, in part due to a decline in breast meat deposition. Dilution of the diets increased production costs and significantly delayed the age at which the birds would reach market weight. Adding extra synthetic amino acids to compensate for lower levels of soybean meal helped to provide some recovery in bird performance and meat yield but this supplementation was not economical due to the high cost of the synthetic amino acids, (data not shown).

TABLE 10. Effect of diluting the soybean meal in turkey tom diets with wheat to produce diets with lower levels of amino acids, 41 - 117 days of age

	Level of dilution[1]		
	None	Medium	High
Live performance			
Body weight gain, kg	11.286	10.095	9.375
Feed:gain	2.414	2.545	2.608
Carcass characteristics			
Carcass yield, % of live wt.	78.2	76.1	75.6
Breast meat, % of carcass	28.2	26.8	25.6
Economic performance			
Poult + feed cost, cents/kg shipped[2]	91.8	95.0	93.9

[1] The lysine was reduced to 89% of the control level at 41 days of age in both the medium and high dilution treatments, declining to 81% and 73% of control levels respectively by 94 days of age.

[2] Based on ingredient prices in Saskatoon from September,1995 to August, 1997. Milling/trucking charge of $40/tonne added to all rations.

B. Response of Broiler Chickens to Wheat Dilution

Breast meat on a broiler chicken accounts for only about 12% of body weight gain at market age, and unlike turkeys, neither the percentage of breast meat nor the eviscerated carcass yield increases noticeably as live weight increases. The lower rate of lean muscle mass deposition helps to explain the differences in how chickens and turkeys react to wheat dilution. In one chicken trial, the soybean and meat meal as well as synthetic amino acids were replaced with wheat to produce diets with as little as 77.5% of the crude protein and amino acids as the control rations (Table 11). The control rations were ones that had been used successfully in previous trials at the University of Saskatchewan. The broilers slowed growth rate, increased feed:gain and decreased percentage of breast meat yield as the protein was diluted but the change was less noticeable than observed with turkeys. The pullets were especially tolerant to wheat dilution and did not display any substantially slowing in body weight gain. Feed:gain ratio was the variable most affected by wheat dilution in both males and females. Because of the limited effect of on breast meat yield,

carcass yield was not greatly affected as protein and amino acids levels declined. Economically, diluting the protein meals and synthetic amino acids lowered the production cost for females but not males, in contrast to the marked increase in cost with turkeys. Another difference between the two types of birds was that the chickens did not respond positively to extra synthetic amino acid fortification as the soybean and meat meal was diluted, (data not shown).

TABLE 11. Performance of male and female broilers fed diets in which the soybean and meat meal were diluted with wheat to give different levels of crude protein & amino acids.

	Crude protein, lysine, methionine + cysteine, % of controls							
	Males				Females			
	100	92.5	85.0	77.5	100	92.5	85.0	77.5
Live Performance from 14 to 41 days								
Body weight gain, kg	2.19	2.18	2.11	1.99	1.79	1.79	1.77	1.77
Feed:gain	1.89	1.90	1.95	2.01	2.00	2.00	2.05	2.08
Carcass characterisitics								
Carcass yield, % of live wt.	62.1	62.5	61.4	62.6	61.6	62.2	61.9	63.0
Breast meat, % of carcass	20.4	19.6	19.5	19.0	20.3	20.4	20.4	19.2
Economic performance								
Chick + feed, cents/kg shipped	78.7	79.0	79.3	78.9	84.5	81.1	82.5	81.5

To take a more precise look at the effect of diluting broiler rations, it was possible to average the results from two trials where the control rations were similar and were diluted with wheat to lower the crude protein and lysine to 85% of control levels. The wheat dilution reduced market weight by 2.5%, eviscerated carcass yield by 0.2% and based on one of the trials, reduced breast meat on the carcass by 0.4%. In the finisher stage, the broilers fed the diluted rations gained 81 g/day and had a feed:gain of 2.331 from 4 to 6 weeks of age on finisher rations costing an average of $242/tonne at 1995 to 1997prices. Using these averages, methods of obtaining the same amount of breast meat from broilers fed control and diluted rations were compared, assuming the control birds were marketed at 1.900 kg, 65% carcass yield and 21% breast meat yield:

1) Raising broilers on the control rations resulted in 1.900 kg birds, containing 0.259 kg of breast meat per bird and averaging a feed + chick cost of 81.1 cents/kg shipped.

2) Raising broilers on diluted rations to same age as the control birds resulted in 1.853 kg birds, containing 0.247 kg of breast meat per bird and averaging a feed + chick cost of 79.9 cents/kg shipped. To obtain the same kg of breast meat from the flock, 5% more chickens would need to be deboned.

3) Raising broilers on diluted rations to same breast meat content as the control birds resulted in birds that were shipped 1 day later, weighed 1.940 kg, contained 0.259 kg

breast meat per bird and averaged a feed + chick cost of 78.9 cents/kg shipped. The production cost was lowered because of the low cost of the diluted finisher diet and spreading of the chick cost over more kg of live weight.

Which of these options was best would depend on a number of factors including the labour cost of deboning the birds, the mix of cut up and whole birds needed by the processor's marketing department and the cost of keeping chickens in the barn an extra day. If maximizing the weight of breast meat on each bird in the fewest numbers of days was critical, then the birds would need to grown on the control rations even if the diluted rations tended to offer a lower cost of production.

SUMMARY: FEEDING WHOLE GRAIN AND DILUTED RATIONS

Chickens and turkeys react the same to whole grain diets but because turkeys are marketed at later ages, they are better suited to diets containing high levels of whole grain. It can take 6 weeks of whole grain feeding for a bird's gizzard to obtain optimum muscle mass and by the time a broiler chicken is ready for market it will just be starting to utilize whole grain as efficiently as mash or pelleted grain. If a producer does not want to sacrifice bird performance, broilers should not be fed over 30% whole grain. Turkeys, on the other hand, have time to develop gizzards capable of efficiently utilizing high levels of whole grain and also benefit from improved skeletal health. The performance of turkeys over the life of the flock is not greatly affected by a small loss in early gain and feed efficiency and turkeys can be successfully fed rations containing 50% or more whole grain.

While turkeys are more suited to high levels of whole wheat or barley than broiler chickens, the opposite is true for wheat dilution of the protein meal and synthetic amino acids in the feed. When crude protein and amino acid levels are dropped below the recommendations of NRC (1994), the growth rate and meat yield of turkeys is reduced significantly. Breast meat and lean tissue deposition make up a large part of the turkey's body weight gain and high levels of protein and amino acids are required. For broiler chickens, the loss in performance is far less noticeable and at times, dilution of chicken rations will be economical. It appears that turkeys would benefit most from rations containing high levels of whole grain combined with a balanced supplement (no dilution) while broiler chickens will sometimes benefit from rations diluted with low levels of whole (or pelleted) grain.

Whole grain combined with a pelleted supplement offers a viable alternative for poultry producers on the Prairies. When used properly, it allows them to achieve lower feed costs without sacrificing growth rate or investing in expensive on-farm feed mixing equipment. It allows feed companies to offer an economical alternative to on-farm mixing where they still sell considerable tonnage to their customers. At the same time, feed mills may be able to expand their markets because pelleted supplements can trucked further than complete feed and can be used to feed more birds from a mill's existing capacity.

APPRECIATION

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EXPERIMENT 1

LIVE PERFORMANCE AND HEALTH OF BROILER CHICKENS FED DIETS DILUTED WITH WHOLE OR CRUMBLED WHEAT

H. L. Classen and C.D. Bennett

ABSTRACT

Some poultry producers on the Prairies have been diluting their feed with whole wheat. Feeding whole grain can reduce feed processing and trucking costs while dilution can reduce ingredient costs. A series of experiments have been planned to produce guidelines on how to add whole grain to poultry feed. In the first experiment broiler chicken diets were diluted with three levels of whole wheat and two levels of crumbled wheat to determine how feeding whole grain and diluting feed with wheat would alter the performance of male and female broilers. Grit was not used. At the maximum level of dilution, the amount of extra wheat added increased from 5% at 11 days of age to 30% at 31 days of age. Body weight, eviscerated carcass weight and mortality at 41 days of age were unaffected by diluting with wheat, in whole or crumbled form. Dilution did not affect the feed conversion of pullets and form did not influence the feed conversion of either sex. Dilution of broiler rations may be profitable because of the limited effect on bird performance. Pelleting all of the wheat in poultry rations is unnecessary because bird performance is unaffected by feeding up to 30% whole grain in the finisher diets.

INTRODUCTION

Most wheat based diets fed to poultry are steam pelleted and offered in pelleted or crumbled form. Early research, however, has indicated that wheat can be fed as whole grain to growing and laying birds with little or no loss in performance (McIntosh *et al.* 1962; O'Neil 1964). More recently, Covasa and Forbes (1994) diluted broiler pullet diets with whole wheat in one trial and ground wheat in another, gradually increasing the dilution rate from 2% at 0 weeks of age to 30% at 7 weeks of age. Final body weight was unaffected by diluting with either form of wheat although diluting with ground but not whole wheat significantly increased feed consumption. Similarly, Rose *et al.* (1995) found that broiler chickens offered diets in which most of the wheat was fed as whole grain had the same body weight and feed conversion as birds fed diets in which all of the wheat was crumbled.

In the present study, broiler chicken diets were diluted with whole or crumbled wheat to determine how feeding whole grain and diluting feed with wheat would alter bird performance. Adding the wheat in different forms helped determine if whole grain could be utilized as efficiently as grain that had been steam pelleted and then crumbled. Feeding whole grain could significantly reduce feed milling costs by eliminating the need for steam pelleting a large portion of the ration. Diluting rations with wheat could be economical if the effect on bird performance is small.

MATERIALS AND METHODS

Commercial day-old male and female broiler chicks were housed in straw-litter pens in three environmentally controlled rooms with 12 pens per room. The males and females were reared in separate pens with 51 chicks started per pen (2.3 x 2 m). All birds were fed the same crumbled starter diet (Table 1) and reared under an increasing lighting program (Classen and Riddell 1989). Initial room temperature was 32°C and was then gradually decreased according to usual brooding practices. Supplemental heat was provided by hot water pipes. All diets used in the study were supplemented with wheat and barley enzymes.

At 11 days of age, the number of chicks in each pen was equalised at 49 per pen to compensate for differences in early mortality. At this time, three pens of pullets and three pens of cockerels were assigned to each of six dietary treatments. In the control treatment, the birds were fed crumbled starter from 11 to 21 days, crumbled grower from 21 to 31 days and pelleted finisher from 31 to 41 days of age (Table 1). Birds in the five remaining treatments were fed the same starter, grower and finisher diets at the same ages as the control birds. After the feed in these treatments had been pelleted or crumbled, however, it was weighed into a paddle mixer and diluted with whole wheat, crumbled wheat or a 50:50 mixture of the two forms of wheat. The crumbled wheat used to dilute the diets had been finely ground and then steam pelleted prior to crumbling. The appropriate dilution rates for all dietary treatments are displayed in Table 2. As an example, the finisher in the low whole wheat treatment was diluted with 15% whole wheat, producing a 85:15 mixture of pelleted finisher and whole wheat. The same source of wheat containing 13.6% crude protein was used for the starter, grower and finisher rations as well as the whole and crumbled wheat. No grit was supplied to birds in any of the treatments.

Body weight, on a pen basis, was determined on days 11, 21, 31 and 41 and feed intakes were recorded for the corresponding periods. Feed:gain ratios were calculated using the above data with a correction for mortality in which the weight of the dead birds was included in the bird weight at the end of each period. Dead birds were recorded daily, weighed and stored at 5°C until post mortem examination.

After processing at 41 days of age, the eviscerated carcasses of 40 pullets and 40 cockerels from each treatment were randomly selected from the killing line and weighed. At the same time, 20 gizzards from both males and females in the control, high whole wheat and high crumbled wheat treatments were weighed before and after removal of digesta contents.

Statistical analyses were computed using SAS Institute, Inc. (1990). Response variables were statistically analysed as a two-way analysis of variance with diet and sex as the independent variables. Where appropriate, means were separated using Tukey's t-test and differences were considered significant when $P<0.05$.

RESULTS

The effects of dietary treatment on body weight, feed consumption and feed:gain ratio are shown in Tables 3, 4 and 5. Cockerels were heavier, had higher feed consumption and

achieved a lower feed:gain ratio than the pullets. Body weight and feed consumption were unaffected by dilution of the feed with whole or crumbled wheat. Compared to the control diets, feed:gain ratio was increased by diluting the grower diet with the highest level of crumbled wheat or whole plus crumbled wheat and diluting the finisher diet with the highest level of whole wheat. The cumulative feed:gain ratio of the cockerels but not the pullets was increased at the highest level of dilution regardless of the form of wheat used.

Total mortality and cause of mortality from day 11 to 41 were unaffected by diluting the diets with whole or crumbled wheat (Table 6). Cockerels had higher total mortality and more mortality due to sudden death syndrome and ascites/right heart failure than the pullets. The pullets, however, had a higher incidence of spondylolithesis than the cockerels.

Eviscerated carcass size was unaffected by dietary treatment although the cockerels had larger carcasses than the pullets (Table 7). Feeding whole wheat but not by feeding crumbled wheat (Table 7) increased gizzard size, both full and empty. Cockerels had heavier gizzards than pullets.

DISCUSSION

The gizzard of commercial broilers can develop the ability to process whole wheat fast enough to maintain rapid growth rates. Even at the highest level of whole wheat addition, the body weight and feed intake of the birds was similar to birds fed diets with no whole wheat. An ability to maintain growth rates while consuming diets containing high amounts of whole wheat has been found by other researchers (Rose and Michie 1982; Leeson and Caston 1993; Covasa and Forbes 1994). Some previous research had shown that early growth rates were depressed with whole wheat feeding but in these previous cases the birds were very quickly exposed to high levels of whole wheat (McIntosh *et al.* 1962; Cowan and Michie 1978). In this trial, the whole wheat was introduced at the 5% level, allowing the gizzard and the rest of the intestinal tract time to adapt to digesting whole wheat. By the end of the trial, the empty gizzard of a bird on the highest level of whole wheat was 33% heavier than that of a bird fed no whole wheat, a finding similar to that of Covasa and Forbes (1994).

Dilution of the diets used in this study did not alter the nutrient content of the feed enough to depress live body weight or eviscerated carcass weight. Covasa and Forbes (1994) also found that the body weight and "carcass characteristics" of pullets were not affected by diluting conventional broiler diets. In the present study, diluting the feed increased the feed:gain ratio of the cockerels but not the pullets, perhaps because pullets require less protein than cockerels. The increase in feed:gain ratio was likely due to dilution and not an inability to digest whole wheat because the feed:gain ratio of birds given feed diluted with high levels of whole or crumbled wheat was the same.

Dilution of the nutrients and medication in the feed did not increase skeletal problems or coccidiosis. Previous research has shown that completely removing the limestone, dicalcium phosphate or vitamins and micro-minerals in the last week before marketing broilers does not hurt live bird performance and so the limited amount of dilution in the present study would not be expected to have serious consequences (Skinner *et al.* 1992 a,b; Chen and Moran 1994). The only significant difference observed in skeletal health in

this study was that pullets had a higher incidence of spondylolithesis than cockerels, a finding already noted in a survey of skeletal problems in broilers (Riddell and Springer 1985). While feeding whole wheat has been demonstrated to reduce coccidiosis challenge (Cumming 1992), none of the birds died from coccidiosis regardless of the form in which the wheat was fed.

Grinding and pelleting all of the wheat in poultry rations is not necessary. At least when whole wheat is gradually introduced to the rations, growth rate is not depressed and feed:gain is not changed up to the levels of whole wheat used in this trial. Because of the limited effect on bird performance, diluting broiler rations with whole or crumbled wheat may be profitable in years when wheat is inexpensive. Feeding whole wheat could reduce feeding milling costs without harming bird performance on the farm.

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TABLE 1. Percentage ingredient composition of the control broiler diets

Ingredients	Broiler starter	Broiler grower	Broiler finisher
Wheat	41.2	47.8	49.1
Barley	20.0	20.0	25.0
Soybean meal	26.0	20.0	14.1
Meat meal	4.0	4.0	4.0
Tallow	4.24	3.59	3.24
Canola oil	1.00	1.00	1.00
Limestone	0.020	0.032	0.037
Dicalcium phosphate	0.671	0.697	0.724
Vitamin/Mineral premix[1]	2.00	2.00	2.00
Salt	0.279	0.277	0.278
DL-Methionine	0.192	0.162	0.128
Lysine-HCl	0.078	0.051	0.151
Coxistac[2]	0.100	0.100	0.100
Stafac[3]	0.050	0.050	0.050
Avizyme TX[4]	0.100	0.100	0.100
Avizyme SX[4]	0.100	0.100	0.100
Calculated analysis			
Crude protein (%)	22.0	20.0	18.0
Metabolizable energy (MJ/kg)	12.47	12.47	12.47
Calcium (%)	0.95	0.95	0.95
Available phosphorus (%)	0.47	0.47	0.47
Sodium	0.16	0.16	0.16
Methionine	0.52	0.46	0.40
Methionine and cysteine (%)	0.86	0.77	0.67
Lysine (%)	1.21	1.03	0.95

[1] The vitamin/mineral premix supplied per kilogram of complete feed: vitamin A, 11,000 I.U.; vitamin D_3, 2200 IU; vit E, 30 IU; menadione, 2 mg; thiamine, 1.5 mg; riboflavin, 6 mg; niacin, 60 mg; pyridoxine, 5 mg; vit B_{12}, 0.02 mg; pantothenic acid 10.0 mg;folic acid, 0.6 mg; biotin, 0.15 mg; choline, 400 mg; vitamin C, 50 mg; iron, 80 mg; zinc, 80 mg; manganese, 80 mg; copper, 10 mg; iodine, 0.8 mg; cobalt, 0.25 mg; selenium 0.3 mg; antioxidant, 0.625 mg; calcium 4477 mg; phosphorous 739 mg.
[2] Pfizer Canada Inc., Animal Health Division, Pointe-Claire, PQ H9R 4V2, Canada.
[3] SmithKline Beecham Animal Health, Mississauga, ON L5L 4X4, Canada.
[4] Finnfeeds International, Marlborough, Wiltshire, SN8 1AA, U.K.

TABLE 2. Levels of dilution[1] with whole and/or crumbled wheat in each treatment

Dilution level[1]						
Whole wheat	Zero	Low	Medium	High	Zero	Medium
Crumbled wheat	Zero	Zero	Zero	Zero	High	Medium
Starter, 11-21 days						
Whole wheat	0	5	5	5	0	2.5
Crumbled wheat	0	0	0	0	5	2.5
Grower, 21-31 days						
Whole wheat	0	10	15	20	0	10
Crumbled wheat	0	0	0	0	20	10
Finisher, 31 to 41 days						
Whole wheat	0	15	22.5	30	0	15
Crumbled wheat	0	0	0	0	30	15

[1] The dilution rates are the percentage of whole and/or crumbled wheat in the feed after it has been diluted.

TABLE 3. Effect of diluting broiler feed with different levels of whole and/or crumbled wheat on body weight (kg bird^{-1})

Dilution Level								
Whole wheat	Zero	Low	Medium	High	Zero	Medium		
Crumbled Wheat	Zero	Zer0	Zero	Zero	High	Medium	Average	SEM
11 days of age								
Pullets	0.233	0.222	0.224	0.224	0.224	0.234	0.227^{A}	0.002
Cockerels	0.236	0.240	0.225	0.238	0.230	0.236	0.234^{B}	0.002
Average	0.235	0.231	0.224	0.231	0.227	0.235	0.230	0.002
21 days of age								
Pullets	0.720	0.701	0.705	0.713	0.710	0.730	0.713^{A}	0.005
Cockerels	0.777	0.787	0.759	0.784	0.774	0.778	0.776^{B}	0.005
Average	0.749	0.744	0.732	0.748	0.742	0.754	0.745	0.006
31 days of age								
Pullets	1.393	1.362	1.380	1.385	1.384	1.408	1.385^{A}	0.009
Cockerels	1.560	1.581	1.530	1.573	1.533	1.554	1.555^{B}	0.008
Average	1.476	1.472	1.455	1.479	1.458	1.481	1.470	0.016
41 days of age								
Pullets	2.166	2.100	2.120	2.131	2.122	2.139	2.130^{A}	0.012
Cockerels	2.488	2.423	2.415	2.398	2.407	2.399	2.422^{B}	0.012
Average	2.327	2.261	2.267	2.265	2.265	2.269	2.276	0.026

^{A,B} The effect of sex was significant for all variables ($P<0.05$). No dietary effects were significant ($P>0.05$).

TABLE 4. Effect of diluting broiler feed with different levels of whole and/or crumbled wheat on feed consumption (kg bird[1])

Dilution level Whole wheat Crumbled Wheat	Zero Zero	Low Zer0	Medium Zero	High Zero	Zero High	Medium Medium	Average	SEM
11 to 21 days of age								
Pullets	0.717	0.689	0.694	0.703	0.700	0.714	0.703[A]	0.004
Cockerels	0.741	0.762	0.743	0.764	0.758	0.744	0.752[B]	0.005
Average	0.729	0.726	0.719	0.734	0.729	0.729	0.727	0.005
21 to 31 days of age								
Pullets	1.186	1.156	1.188	1.217	1.210	1.214	1.195[A]	0.010
Cockerels	1.301	1.347	1.347	1.393	1.367	1.355	1.352[B]	0.010
Average	1.244	1.252	1.268	1.305	1.288	1.285	1.273	0.015
31 to 41 days of age								
Pullets	1.662	1.541	1.594	1.638	1.633	1.642	1.618[A]	0.015
Cockerels	1.804	1.763	1.825	1.785	1.851	1.763	1.799[B]	0.014
Average	1.733	1.652	1.710	1.712	1.742	1.702	1.709	0.018
11 to 41 days of age								
Pullets	3.534	3.335	3.428	3.519	3.524	3.485	3.471[A]	0.015
Cockerels	3.730	3.816	3.894	3.887	3.906	3.720	3.825[B]	0.014
Average	3.632	3.576	3.661	3.703	3.715	3.602	3.648	0.037

[A,B] The effect of sex was significant for all variables ($P<0.05$). No dietary effects were significant ($P>0.05$).

TABLE 5. Effect of diluting broiler feed with different levels of whole and/or crumbled wheat on feed:gain ratio (kg kg^{-1})

Dilution level								
Whole wheat	Zero	Low	Medium	High	Zero	Medium		
Crumbled Wheat	Zero	Zer0	Zero	Zero	High	Medium	Average	SEM
11 to 21 days of age								
Pullets	1.475	1.439	1.448	1.442	1.446	1.449	1.450^{A}	0.006
Cockerels	1.377	1.400	1.399	1.412	1.405	1.406	1.400^{B}	0.009
Average	1.426	1.420	1.423	1.427	1.426	1.427	1.425	0.007
21 to 31 days of age								
Pullets	1.770	1.774	1.771	1.810	1.799	1.816	1.790^{A}	0.009
Cockerels	1.695	1.726	1.747	1.770	1.824	1.774	1.756^{B}	0.012
Average	1.732^{a}	1.750^{ab}	1.759^{ab}	1.790^{ab}	1.811^{b}	1.795^{b}	1.773	0.008
31 to 41 days of age								
Pullets	2.221	2.137	2.212	2.248	2.264	2.272	2.226^{A}	0.015
Cockerels	2.038	2.142	2.116	2.246	2.191	2.209	2.157^{B}	0.022
Average	2.130^{a}	2.140^{ab}	2.164^{ab}	2.247^{b}	2.227^{ab}	2.240^{ab}	2.191	0.014
11 to 41 days of age								
Pullets	1.870	1.825	1.854	1.882	1.885	1.889	1.868^{A}	0.007
Cockerels[1]	1.749^{a}	1.798^{ab}	1.808^{ab}	1.854^{b}	1.811^{b}	1.839^{b}	1.817^{B}	0.011
Average	1.810^{a}	1.812^{a}	1.831^{ab}	1.868^{b}	1.871^{b}	1.864^{b}	1.843	0.008

[A,B] The effect of sex was significant for all variables ($P<0.05$).
[a,b] Mean values within a row with no common superscripts are significantly different ($P<0.05$).
[1] Significant dietary treatment x sex interaction ($P<0.05$).

TABLE 6. Effect of dilution with whole and/or crumbled wheat on the mortality of pullet and cockerel broilers from day 11 to 41 (%)

Dilution level										
Whole wheat	Zero	Low	Medium	High	Zero	Medium				
Crumbled Wheat	Zero	Zero	Zero	Zero	High	Medium	Pullets	Cock.	Average	SEM
Cause of mortality										
SDS[1]	4.06	1.67	1.02	2.37	1.35	3.40	1.03[A]	3.59[B]	2.31	0.49
Ascites/RHF[2]	1.34	1.01	1.35	0.34	2.06	2.71	0.46[A]	2.47[B]	1.47	0.36
Rotated tibia	0.35	0.35	0.00	0.00	0.00	0.35	0.35	0.00	0.17	0.10
Valgus/varus legs	0.68	0.33	0.33	0.35	0.00	1.03	0.46	0.45	0.45	0.16
Spondylolithesis	0.69	0.35	0.00	0.67	0.35	0.33	0.80[A]	0.00[B]	0.40	0.14
TD[3]	0.35	0.33	0.00	0.34	0.00	0.00	0.12	0.22	0.17	0.10
Serositis[1]	0.00	0.34	0.00	0.00	0.67	0.34	0.11	0.34	0.22	0.13
Arthritis	0.00	0.00	0.35	0.33	0.00	0.00	0.12	0.11	0.11	0.08
Other	0.00	1.03	1.01	0.34	1.02	0.34	0.68	0.57	0.63	0.14
TOTAL	7.46	5.40	4.06	4.74	5.44	8.50	4.11[A]	7.75[B]	5.93	0.71

[A,B] Means for pullets and cockerels within a row with different superscripts are significantly different ($P<0.05$). No significant differences due to dietary treatment were observed ($P>0.05$).

[1] Serositis included birds dying from airsacculitis, pericarditis, peritonitis and perihepatitis.

TABLE 7. Effect of dilution with whole and/or crumbled wheat on the eviscerated carcass weight and gizzard weight of pullet and cockerel broilers at 41 days of age

Dilution level								
Whole wheat	Zero	Low	Medium	High	Zero	Medium		
Crumbled Wheat	Zero	Zer0	Zero	Zero	High	Medium	Average	SEM
Eviscerated carcass weight (kg)								
Pullets	1.350	1.322	1.334	1.328	1.327	1.337	1.333^{A}	0.009
Cockerels	1.579	1.546	1.466	1.498	1.512	1.509	1.515^{B}	0.012
Average	1.465	1.434	1.400	1.413	1.420	1.423	1.424	0.012
Full gizzard weight (g)								
Pullets	24.1			37.2	27.0		29.4^{A}	1.1
Cockerels	30.1			40.7	28.6		33.2^{B}	1.1
Average	27.1^{a}			39.0^{b}	27.8^{a}		31.3	0.8
Empty gizzard weight (g)								
Pullets	22.6			31.3	24.2		26.0^{A}	0.7
Cockerels	27.2			35.4	26.0		29.5^{B}	0.8
Average	24.9^{a}			33.4^{b}	25.1^{a}		27.8	0.5

^{A,B} The effect of sex was significant for all variables ($P<0.05$).
^{a,b} Mean values within a row with no common superscripts are significantly different ($P<0.05$).

EXPERIMENT 2

WHOLE WHEAT AND HIGH WHEAT DIETS FOR TURKEY TOMS

H.L. Classen and C.D. Bennett

ABSTRACT

Two turkey trials were completed to investigate feeding whole wheat plus a pelleted supplement as well as diluting turkey rations with whole or pelleted wheat. In these turkey tom feeding trials, very little difference existed between diluting with whole or pelleted wheat. Replacing the soybean meal and added fat in turkey tom diets with either form of wheat reduced growth rate, increased feed:gain and decreased carcass and meat yield. Supplementing diluted diets with high levels of synthetic lysine, methionine and threonine restored much but not all of the lost performance. Due to the high cost of synthetic amino acids, however, no clear economic advantage could be obtained from such fortified diets. The best opportunity to lower feed costs may come from reducing just the added fat in turkey rations since toms grew well on low fat diets. If dilution reduces the amino acid intake below NRC (1994) recommendations, performance will suffer.

The easiest application of whole grain feeding is not to dilute diets but to use it as a method of on-farm mixing. The equipment needed to add whole grain on the farm is inexpensive and mixing whole grain with a pelleted supplement can produce excellent bird performance. Gradually increasing the level of whole wheat to 35% of the finisher ration resulted in market weights, feed efficiency and carcass characteristics which were the same as an all pelleted diet. Increasing the whole wheat to 50% of the diet increased feed:gain but may still be economical in some situations. While the economics will depend on trucking costs and mill margins, a potential return 2.7 cents/kg shipped has been identified.

INTRODUCTION

At the present time, most wheat based diets fed to poultry are steam pelleted and offered in pelleted or crumbled form. Research in the 1950's and 1960's, however, indicated that the breeds of growing and laying birds that were common at that time could use whole grain with little or no loss in performance (McIntosh *et al.* 1962; O'Neil 1964). More recently, whole wheat feeding has become common in commercial chicken flocks in Europe and recent research from Europe indicates that whole grain can be used efficiently by chickens (Covasa and Forbes 1994; Rose *et al.* 1995).

While some turkey self-selection trials have been done, no practical research has been published on how to feed whole grain to turkeys. One large integrator in the U.K. has fed whole wheat on a routine basis to turkey toms, diluting the grower feed at 8 weeks of age with 5% whole wheat and increasing to 40% dilution by 15 weeks of age. This integrator keeps the toms on the same grower but increases the amount of whole wheat dilution each week to produce rations with progressively lower levels of protein. The advantages to the integrator's feed mill include lower pelleting cost and longer feed production runs because one grower ration is being produced instead of two growers and one finisher. While the

whole wheat is added at the mill in this case, trucking costs would be reduced if it was added at the farm instead.

While it appears that whole grain can be fed to turkeys under commercial conditions, the ages and levels at which it should be included in the diet have not been researched. Also, since some turkey and chicken growers have been diluting their rations with whole wheat, the effect of dilution needs to investigated to determine the economic trade off between lower feed cost and reduced bird performance. Practical guidelines for whole grain feeding need to be determined on the basis of scientific research.

MATERIALS AND METHODS

A total of 1620 day old tom poults were housed 30 birds each in straw litter pens (2m x 4.6m) in 9 rooms, each room containing 6 pens. The birds in 3 rooms were assigned to Trial A and the remaining birds were in Trial B. Birds were reared under an increasing lighting program (Classen *et al.* 1994). The toms were kept in rings inside each pen until 11 days of age. Birds dying in the first 2 weeks were replaced and all dead birds were collected daily, weighed and stored at 5°C until post mortem examination.

The birds were fed Prestarter (0-3 wks) as crumbles and Starter (3-6 wks) as crumbles or a mixture of crumbles and whole wheat. In treatments where whole grain was to be fed in the grower and finisher, (Trt 2,3 in Trial A; Trt 2,3,6 in Trial B), 5% whole wheat was included in the starter. The whole grain was mixed with the crumbles in a ribbon mixer after the crumbles had been made. Any whole grain in the starter simply replaced wheat already in the diet and was not used to dilute any nutrients or ingredients. Total amino acid and metabolizable energy levels of the prestarter and starter were formulated to meet or exceed the specifications of NRC (1994) for commercial practice. No grit was supplied at any time during the trials.

During both trials, birds and feed were weighed at each feed change. Feed:gain ratios were calculated using the above data with a correction for mortality in which the weight of the dead birds was included in the bird weight at the end of each period. The mortality correction reduced the variability in the feed conversion numbers, making trends between the treatments more apparent and making the feed conversion more reflective of how well the birds were utilising the feed instead of whether they were living or dying. Cumulative feed conversions, without mortality correction, were also calculated because they better represent the economics of different feeding programs.

Statistical analyses were computed for both trials using SAS Institute Inc. (1990). Response variables were analysed as a two-way analysis of variance with diet and room as the independent variables. Where appropriate, means were separated using Duncan's multiple range test and differences were considered significant when $P<0.05$.

TRIAL A

In Trial A, six pens of toms were assigned to one of three dietary treatments. The toms in Trt 1 were fed no whole grain while those in Trts 2 and 3 were fed medium and high levels of whole grain respectively. The percentage of whole wheat included in the diets in each

treatment is outlined in Table 1. All birds were fed Grower 1 (6 to 9 wks), Grower 2 (9 to 12 wks) and Finisher (12 to 16 wks) formulated to the amino acids specifications suggested for commercial conditions by NRC (1994) but with 100 to 200 kcal/kg less metabolizable energy (Table 2). The growers and finisher were fed as pellets or a mixture of pellets and whole wheat. The birds in Trts 2 and 3 had been fed a starter with 5% whole wheat. The only difference between any dietary treatments was the form of the wheat (whole or steam pelleted). As an example, a tonne of finisher in Trt 3 was identical to a tonne of finisher in Trt 1 except that 500 kg of ground wheat was not incorporated into the pellets but was later added as whole grain.

TRIAL B

In Trial B, 6 pens of turkeys toms were assigned to each of 6 dietary treatments. The toms were fed Grower 1 (6-9 wks), Grower 2 (9-12 wks) and Finisher (12-16 wks) as pellets or a mixture of pellets and whole wheat. In treatments where whole grain was to be fed, (Trts 2, 3 and 6), 5% whole wheat had been included in the starter. Total amino acid and metabolizable energy levels of the control rations (Trt 1) were formulated to meet or exceed the specifications of NRC (1994) for commercial practice. In Trts 2 to 5, extra wheat was added to the feed at the expense of soybean meal, canola oil and synthetic amino acids, producing diets with progressively higher levels of wheat compared to the controls. In Trt 6 the soybean meal and canola oil were replaced with wheat but the synthetic lysine, methionine and threonine levels were adjusted so that total lysine, methionine+cysteine and threonine were maintained at the same levels as in the control diets. In all of the diluted diets, the levels of salt, limestone, dicalcium phosphate, vitamin-mineral supplement, binder and medication were adjusted so that the sodium, calcium, phosphorous, vitamin and mineral as well as binder and growth promotant levels in the feed were the same as in the control treatment. The extra wheat was added as whole grain in Treatments 2, 3 and 6 while it was ground and included in the pellet in Treatments 4 and 5. The ingredient specifications of the growers and finisher are detailed in Tables 3 and 4 while Table 5 outlines the levels of wheat dilution and whole or pelleted wheat in the diets.

As an example, the finishers in Trts 3 and 5 were formulated by removing 50% of the soybean meal, canola oil and synthetic amino acids from the control finisher diet and replacing them with an equal amount of wheat. This is the 50% wheat dilution referred to in Table 5. A further, small reduction (2.2%) was made in these ingredients and they were replaced with adequate levels of micro ingredients to maintain the vitamin, mineral, binder and medications at the same level as in the controls. The only difference between Trt 3 and 5 was that half of the ration in Trt 3 was fed as whole wheat instead of as pelleted wheat. The finisher in Trt 6 was formulated similarly to Trt 3 except that 50% of the soybean meal and canola oil were replaced with wheat and a further 2.5% reduction was then made to restore not only the vitamin, minerals and medications but also the lysine, methionine + cysteine and threonine to the same level as in the control finisher.

Carcass yield and meat yield were measured for 30 birds per treatment when the toms were marketed at 16 weeks of age. The live, unfasted body weight of each bird was individually determined the day before the birds were shipped to a processing plant. After evisceration, the birds were packed in ice and stored at -1°C for 2 days prior to meat yield

determination. Carcass components were weighed as follows: whole carcass (neck excluded), *Pectoralis major, Pectoralis minor*, breast skin, keel bone, thigh meat, thigh skin, thigh bone (femur), drumsticks (skin and bone included), wings (skin and bone included) and rack (carcass remaining after removal of breast, wings and legs).

METABOLIZABLE ENERGY DETERMINATION

Apparent metabolizable energy at was determined for pelleted wheat versus whole wheat and a complete pelleted diet versus a similar diet with 50% whole wheat. Starting at 4 weeks of age, 28 turkey toms were reared on a grower formulated to contain 22% crude protein, 1.30% total lysine and 2850 kcal/kg of metabolizable energy. The same source of #3 Grade of Hard Red Spring Wheat that had been used in Trials A and B was used for all 4 test rations. Half of the birds received this diet in completely pelleted form while the other were fed the same ration but with 10% whole grain at 4 weeks of age, 20% at 5 weeks of age and 50% whole grain after 6 weeks of age. The toms reared on whole grain rations were used to test the whole wheat and diet containing 50% whole wheat. At 8 to 11 weeks of age, turkey toms were housed in individual cages and apparent metabolizable energy was determined using a total collection of faeces. Birds were allowed 3 days to acclimatise to the cages and diets before a 4 day collection period. The pelleted and whole wheat was fed to 6 birds each while the complete diets were fed to 8 birds each. Each bird was used to test only one ration or ingredient.

When a diet of whole wheat and pelleted supplement was fed, some of the whole grain settled to the bottom of the feeder and was not consumed by the birds. The feed remaining at the end of the collection period was sieved to establish the percentage of whole wheat and pelleted supplement consumed. The apparent metabolizable energy value was then adjusted back to that of 50:50 mixture using the AME value determined for whole wheat in this same trial. For example, if a bird ate 700 grams of whole wheat and 800 grams of pelleted supplement, the AME value of another 100 grams of whole wheat was used to estimate the AME if the birds had consumed both ingredients equally.

RESULTS AND DISCUSSION

TRIAL A

In Trial A, diets with different levels of whole wheat but identical nutrient and ingredient specifications were compared. Body weight gain was not significantly affected by any level of whole grain feeding and birds could be fed 50% whole wheat in the finisher and still achieve normal growth rates (Table 6). Numerically, the toms in Treatment 2 which were fed 35% whole wheat in the finisher were 0.9% heavier than the control birds fed just pellets while the birds in Treatment 3 were fed 50% in the finisher and were 0.7% smaller than the control birds. This numerical trend is similar to the one found in broiler chicken research which indicates that gradually increasing up to 30% whole wheat in the diet will not change body weight but feeding greater amounts of whole grain will result in a small decline in market weight. At high levels of whole grain feeding, the turkey's gizzard may not be able to grind the grain fast enough to match the growth rate of birds on pellets. Any growth depression in the present trial, however, was small and amounted to only 0.5 days difference in growth between Treatment 1 and Treatment 3 at 16 weeks of age.

Feed efficiency was significantly poorer when the birds were fed a crumbled starter with 5% whole grain compared to one with no whole grain (Table 7). When manufacturing this starter, the crumble had to moved from the pelleter through a series of elevators and then added back to the mixer before it could be mixed with the whole grain. A high level of fines was produced, (20% of the diet would pass through as 1.00 mm sieve), and the turkeys wasted more of this powdery feed. The pelleted growers and finishers were much more durable and fines were not a problem. Differences in feed efficiency on the growers and finisher reflected the ability of turkeys to utilise whole grain and not the durability of the pellet.

When the pelleted growers and finisher were fed, the turkeys' feed:gain was not affected by a moderate level of whole grain. No significant differences in feed conversion were observed between the toms in Trts 1 and 2, although feeding a 35% whole grain finisher in Trt 2 appeared to numerically increase the feed:gain (3.172 vs 3.030). In Trt 3, the feed:gain was significantly increased compared to the controls when Grower 2 containing 35% whole grain was fed (2.418 vs 2.300). Feeding 50% whole wheat in the finisher in Trt 3 did not significantly alter feed:gain but it was numerically higher than in Trt 1 (3.142 vs 3.030). Cumulative feed conversion from 3 to 16 weeks of age, when mortality corrected, was unaffected by feeding the medium level of whole wheat in Trt 2 but was significantly increased by the high level of whole grain in Trt 3 (2.372 in Trt 3 vs 2.279 in Trt 1 and 2.304 in Trt 2). No significant differences occurred when cumulative feed:gain was not corrected for mortality.

These findings were similar to those with broiler chickens which indicate that up to 30% whole grain can be fed without a loss in feed efficiency but above that level feed:gain is increased. It is possible that the gizzard's capacity is exceeded when high levels of whole grain are fed and some of the grain passes into the small intestine partially or totally unground. No research has yet been completed to determine if feeding grit would eliminate the increase in feed conversion when high levels of whole wheat are fed.

No significant differences in total mortality were observed between treatments (Table 8). In Trt 2, the number of birds with pendulous crop was reduced but the number of cannibalised birds was increased compared to the control treatment ($P<0.05$). The reduction in pendulous crop could have occurred because the whole grain was less likely to ferment in the crop. No logical reason for the increase in cannibalism in Trt 2 can be determined when absolutely no cannibalism occurred among the birds in Trt 3.

TRIAL B

In Trial B, the soybean meal and canola oil in turkey rations were replaced with medium or high levels of wheat in either pelleted or whole grain form. The levels of whole grain fed were similar to those used in Trial A. Dilution with pelleted or whole wheat had the same effect on growth rate (Table 9) and no significant differences were observed between the two feed forms (Trts 2 vs 4 and Trts 3 vs 5). As in Trial A, a numerical trend was observed for toms fed a medium level of whole wheat to be slightly heavier (Trt 2 vs Trt4) and those fed a high level to be slightly lighter (Trt 3 vs Trt 5) than birds fed a completely pelleted diet. Overall, diluting with whole or pelleted wheat produced very similar growth rates.

While any differences between whole wheat and pelleted wheat dilution were small,

replacing soybean meal and canola oil with either form of wheat had a dramatic effect on growth rates. Replacing just 15% of the soybean meal and canola oil with wheat in Grower 1, significantly reduced the body weight at 9 weeks of age by an average of 4.2% for Treatments 2 to 5. The body weight reduction become larger as dilution was increased at older ages. A medium level of dilution with either form of wheat significantly reduced body weight at 16 weeks of age compared to the controls, with an average reduction of 11.1% for Trts 2 and 4. A high level of dilution with both forms of wheat significantly reduced 16 week body weight even more, averaging a 14.2% reduction for Trts 3 and 5 compared to Trt 1. The toms fed the most diluted diets would require an extra 14 days to attain the 16 week market weight of the birds on the control rations.

Adding extra synthetic amino acids restored much of the body weight lost at the high level of dilution. In Trt 6, feeding turkey toms extra synthetic amino acids produced market body weights significantly greater than any birds fed diets diluted with high levels of wheat and some of those fed rations diluted with medium levels of wheat (Trt 4). While body weight at 16 weeks of age was still lower than the control birds, the toms needed only 5 days longer to achieve the same market weight as those fed the control diets. The toms fed the extra synthetic amino acids gained 9 days of growth compared to high dilution with no extra amino acid supplementation (Trt 3). This enhanced performance occurred even though the diets were still very low in added fat. Turkey toms could grow at close to maximum rates on low fat levels as long as amino acid levels were maintained, a conclusion supported by the fact that the toms grown on low energy and high energy control diets in Trials A and B respectively had very similar market weights.

As in Trial A, a high level of fines occurred in the starter ration containing 5% whole wheat and all of the turkeys fed whole grain had a significantly poorer feed:gain than those in some or all of the treatments fed the starter with no whole grain (Table 10). In the pelleted grower and finisher diets, fines were not a problem and feeding moderate levels of whole wheat did not alter feed:gain. The only other significant difference between the two feed forms occurred between 9 and 12 weeks of age when the birds in Trt 3 were fed 35% whole grain and had a higher feed:gain than those in Trt 5 (2.681 vs 2.550). Feeding 35% and 50% whole grain in the finisher in Trts 2 and 3 resulted in numerically higher feed:gain than Trts 4 and 5. Feeding a high level of whole wheat resulted in a higher cumulative feed:gain, when mortality corrected, for Trt 3 than Trt 5 (2.512 vs 2.414). Overall, the effect of feeding whole grain was similar to that in Trial A with significant differences occurring when more than 30% whole grain was fed.

While some differences due to feed form were observed, the overall response to diluting with either form of wheat was the same. At 6 to 9 weeks of age, the feed:gain of the controls was significantly lower than the toms in Trt 4 and numerically lower than the birds in all of the other treatments. After 9 weeks of age, when Grower 2 and Finisher were fed, the control birds had significantly better feed conversions than the birds in almost all of the other treatments, the only exception being Trt 4 from 9 to 12 weeks of age. For each form of wheat, medium level dilution of Grower 2 or Finisher produced a superior feed:gain than high level dilution (Trt 2 vs 4 and Trt 3 vs 5). The undiluted control diets had significantly better mortality corrected and uncorrected feed:gain from 3 to 16 weeks of age than any of the diluted treatments. Dilution with wheat increased feed:gain and the effect was greater at higher levels of dilution.

Supplementing the feed with extra synthetic amino acids in Trt 6 improved feed efficiency but did not restore it to the same level as the control rations. After 9 weeks of age, the birds in Trt 6 had a significantly better feed:gain than those in Trt 3 which were fed the same level of whole wheat but without extra synthetic amino acids. The cumulative feed:gain, when mortality corrected, was similarly affected. The difference in feed:gain would have been even more noticeable if the birds had been grown to the same body weight instead of the same age. The toms in Trt 3 would take several more days to reach the same body weight as Trt 6 and their feed:gain would have been even higher. Despite this improvement, feed:gain after 9 weeks of age and cumulative feed:gain was poorer in Trt 6 than in the control treatment. Since the feed in Trt 6 had low levels of added fat, the higher feed:gain was not unexpected.

Diluting with whole or pelleted wheat produced birds with similar carcass weights and meat yields (Table 11). No significant differences were observed between the 2 types of wheat at the same dilution level (Trt 2 vs. 4 and Trt 3 vs. 5). As long as nutrient levels in the feed were similar, the form of wheat fed to turkeys did not affect the characteristics of the bird shipped to the processing plant. Whether the grain was pelleted or whole, a similar amount of offal would be discarded by the plant and carcass yield would be the same for both feeding programs. Feeding whole grain did not have any negative consequences for the amount of breast meat or other valuable cuts that could be obtained by the plant. If diets with similar nutrient specifications are compared, whole grain feeding is not a concern for processing plants.

Dilution of nutrients in the feed with either form of wheat, however, would significantly reduce carcass weight and meat yield at 16 weeks of age. Compared to toms on the highest level of wheat dilution in Trts 3 and 5, the control birds had significantly heavier carcass weights and higher percentages of eviscerated carcass, *Pectoralis major*, *Pectoralis minor*, total breast meat, total breast and thigh meat, and drumsticks. The trend was the same at the medium level of dilution except that the toms in Trts 2 and 4 had the same percentage of *Pectoralis minor* as the toms in Trt 1. Supplementation with extra synthetic amino acids (Trt 6) restored the percentage of *Pectoralis major*, *Pectoralis minor*, total breast and thigh meat, and drumsticks to that in the undiluted controls.

Total mortality was not significantly altered by any of the feeding programs and none of the major causes of mortality were statistically different between treatments (Table 13).

The metabolizable energy that the turkey toms could derive on an "as is" basis from whole wheat (2929 $\pm$ 15.2 kcal/kg) was virtually identical that from pelleted wheat (2939 $\pm$ 31.6 kcal/kg). The dry matter of the whole and pelleted wheat were also the same (91.3 $\pm$ 0.09% vs 91.4 $\pm$ 0.23%). The grower ration with 50% whole wheat had a metabolizable energy value (2951 $\pm$ 24.0 kcal/kg) similar to that of the grower ration with 0% whole wheat (2890 $\pm$ 41.3 kcal/kg). The dry matters of the whole grain and pelleted growers were equally similar (92.8 $\pm$ 0.06% vs 92.4 $\pm$ 0.09%). These results help confirm that turkeys can efficiently utilise whole grain.

ECONOMIC ANALYSIS

The economic return for the different feeding programs was evaluated by calculating the

feed + poult cost / kg shipped. The feed producing the lowest feed + poult cost would provide the best returns. To estimate total feed cost, $40/tonne was added to any portion of a diet that had to be steam pelleted; it was assumed that the pelleted portion of the diet would be purchased from a commercial feed mill and that $5/tonne would be charged for pelleting, $15/tonne for trucking and $20/tonne other milling charges. It was further assumed that the whole grain would be purchased locally and added on the farm. The cost of trucking the grain to the farm from a local grain elevator or grain farm was assumed to the same as trucking it to a commercial feed mill to be processed. Any savings from adding whole grain on the farm would be used to pay the $8,000 to $15,000 cost of setting up the equipment necessary to add grain on the farm.

The feed consumed per kg of turkey shipped to the processing plant was used as a measure of feed intake. This figure was used instead of a mortality corrected feed conversion because it reflected the economic cost of the feed lost when a bird died. Most poultry producers use feed intake per kg of bird shipped when they calculate the returns for their own farms. The poult cost per kg shipped was calculated using a cost of $1.75 per poult placed and dividing that amount by the kg of turkey shipped per poult placed. The feed + poult cost was calculated using feed ingredient prices from October, 1991 and October, 1995 to reflect periods when wheat was expensive and inexpensive ($90/tonne vs $165/tonne).

To estimate the economics of feeding a medium level of whole grain, without dilution, the results of Trts 1 and 2 in Trial A and Trts 2 and 4 in Trial B were averaged. In both trials, these treatments compared feeding no whole wheat to one where whole wheat was gradually increased from 5% in the starter to 35% in the finisher. These treatments compared feed with identical nutrient specifications but different feed forms:

The economics of feeding all pellets was compared to feeding a high level of whole grain using the combined results of Trts 1 and 3 in Trial A and Trts 3 and 5 in Trial B. When the high level of whole grain was fed, the whole wheat was gradually increased from 5% in the starter to 50% in the finisher:

The economic benefit appeared to be greater on the medium than the high level of whole wheat feeding. The medium level of whole grain lowered costs by 2.6 to 2.8 cents/kg compared to the completely pelleted diet while the high level of whole wheat lowered costs by only 1.2 to 1.8 cents/kg. The better feed:gain ratio on the medium level of whole wheat made it more profitable and less affected by changes in the price of wheat. If a farm growing 10,000 toms annually could save 2.7 cents/kg, payback on the whole grain mixing equipment would be 2.5 to 4.6 years.

To estimate the economics of diluting with wheat, the feed + poult cost was compared for turkeys fed diluted diets with zero, medium or high levels of pelleted wheat (Trts 1, 4, and 5 of Trial B). By just examining diets diluted with pelleted wheat, the effect of wheat dilution could be isolated from the economic effect of feeding whole grain. Even when wheat was inexpensive in 1991, the loss in performance on the diluted diets resulted in higher feed+poult cost.

Supplementing a highly diluted feed with extra synthetic amino acids did improve bird performance but because of the expense of the synthetic amino acids did not greatly

improve profitability. Comparing Trt 3 vs Trt 6 in Trial B, the synthetic amino acid fortification would lower cost by 0.8 cents/kg using 1991 ingredient prices but raise it 0.1 cents/kg using 1995 prices. The economics of using synthetic amino acids to help replace large amounts of soybean meal in turkey rations is questionable at this time.

SUMMARY

Nutritionally, very little difference exists between diluting with whole or pelleted wheat. Replacing the soybean meal and added fat in turkey tom diets with either form of wheat will reduce growth rates, increase feed:gain ratio and decrease carcass and meat yield. Supplementing diluted diets with high levels of synthetic lysine, methionine and threonine will restore much but not all of the lost performance. Due to the cost of synthetic amino acids, however, no clear economic advantage can be obtained from such fortified diets. The best opportunity to lower feed costs may come from reducing just the added fat in turkey rations since toms grow well on low fat diets. If dilution reduces the amino acid intake below NRC (1994) recommendations, performance will suffer.

The easiest application of whole grain feeding is not to dilute diets but to use it as a method of on-farm mixing. The equipment needed to add whole grain on the farm is inexpensive and mixing whole grain with a pelleted supplement can produce excellent bird performance. Gradually increasing the level of whole wheat to 35% of the finisher ration will result in market weights, feed efficiency and carcass characteristics the same as an all pelleted diet. Increasing the whole wheat to 50% of the diet will increase feed:gain but may still be economical in some situations. While the economics will depend on trucking costs and mill margins, a potential return 2.7 cents/kg shipped has been identified.

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TABLE 1. Levels of whole wheat fed in Trial A

	Diet and age fed				
Trt.	Prestarter 0 - 3 wks	Starter 3 - 6 wks	Grower 1 6 - 9 wks	Grower 2 9 - 12 wks	Finisher 12- 16 wks
1	0%	0%	0%	0%	0%
2	0%	5%	15%	20%	35%
3	0%	5%	15%	35%	50%

TABLE 2. Percentage ingredient composition of turkey diets in Trial A

Ingredient	Prestarter	Starter	Grower1	Grower2	Finisher
Wheat	48.9	53.7	70.5	80.8	85.2
Soybean meal	38.6	33.5	18.9	8.6	5.0
Meat meal	6.0	6.0	7.0	8.0	7.0
Limestone	1.28	0.98	0.76	0.50	0.55
Dicalcium phosphate	1.63	1.15	0.40	0.01	0.09
Tallow	2.18	3.24	0.00	0.00	0.00
Canola oil	0.00	0.00	0.88	0.57	0.89
Salt	0.24	0.24	0.22	0.20	0.22
DL Methionine	0.22	0.18	0.17	0.12	0.07
Lysine-HCL	0.07	0.12	0.32	0.26	0.16
Threonine	0.00	0.00	0.00	0.12	0.04
Stafac 22	0.10	0.10	0.05	0.05	0.05
Coban 60	0.08	0.08	0.00	0.00	0.00
Ethoxyquin	0.02	0.02	0.02	0.02	0.02
Vitamin/mineral premix	0.50	0.50	0.50	0.50	0.05
Avizyme TX	0.10	0.10	0.10	0.10	0.10
Agri-colloid binder	0.10	0.10	0.10	0.10	0.10
Calculated analysis					
Crude protein (%)	28.0	26.0	22.0	19.0	17.2
AME (kcal/kg)	2800	2900	2900	2950	3000
Calcium (%)	1.30	1.10	0.95	0.85	0.80
Avail. phosphorous (%)	0.70	0.60	0.475	0.425	0.40
Methionine + cysteine (%)	1.05	0.95	0.80	0.65	0.55
Lysine (%)	1.60	1.50	1.30	1.00	0.80
Threonine (%)	1.07	0.99	0.80	0.75	0.60
Sodium (%)	0.16	0.16	0.16	0.16	0.16

TABLE 3. Percentage ingredient composition of grower and finisher diets ir

	Grower 1			Grower 2				
	Trt 1	Trt 2-5	Trt 6	Trt 1	Trt 2, 4	Trt 3, 5	Trt 6	Trt 1
Wheat	63.0	68.1	67.9	71.3	76.4	80.3	79.9	77.4
SBM[1]	28.8	24.3	24.2	20.3	16.0	12.9	12.8	13.4
Limestone	1.56	1.57	1.57	1.42	1.43	1.43	1.43	1.35
Dical.P[1]	1.68	1.70	1.70	1.47	1.49	1.50	1.51	1.39
Canola oil	3.52	2.96	2.95	4.22	3.34	2.68	2.67	5.20
Salt	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
DL MET	0.12	0.10	0.17	0.07	0.05	0.04	0.15	0.04
Lysine HCL	0.20	0.17	0.36	0.11	0.09	0.07	0.37	0.10
Threonine	0.00	0.00	0.07	0.06	0.05	0.04	0.18	0.02
Stafac 22	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ethoxyquin	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Vit/min[1]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Avizyme TX	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Binder[1]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Calculated analysis								
Protein (%)	22.0	20.5	20.7	19.0	17.6	16.6	17.0	16.5
AME (kcal/kg)	3000	2994	2983	3100	3067	3054	3037	3200
Calcium (%)	0.95	0.95	0.95	0.85	0.85	0.85	0.85	0.80
Avail. P (%)	0.475	0.475	0.475	0.425	0.425	0.425	0.425	0.40
MET & CYS (%)	0.80	0.73	0.80	0.65	0.60	0.56	0.65	0.55
Lysine (%)	1.30	1.16	1.30	1.00	0.87	0.78	1.00	0.80
THR (%)	0.83	0.76	0.83	0.75	0.67	0.62	0.75	0.60
Sodium (%)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16

[1] SBM – soybean meal; Dical. P – Dicalcium phosphate; Vit/min – vitamin/mineral premix; Binder

TABLE 4. Levels of wheat dilution (D) and feed form (pelleted/whole grain; P/WW) in Trial B

TRT	Diet and age fed (wks)		
	Grower 1 (6-9 wks)	Grower 2 (9-12) wks	Finisher (12-16 wks)
1	0% wheat D 100% P	0% wheat D 100% P	0% wheat D 100% P
2	15% wheat D 15% WW	20% wheat D 20% WW	35% wheat D 35% WW
3	15% wheat D 15% WW	35% wheat D 35% WW	50% wheat D 50% WW
4	15% wheat D 100% P	20% wheat D 100% P	35% wheat D 100% P
5	15% wheat D 100% P	35% wheat D 100% P	50% wheat D 100% P
6	15% wheat D + extra synthetic amino acids 50% WW	35% wheat D + extra synthetic amino acids 35% WW	50% wheat D + extra synthetic amino acids 50% WW

Note: The dilution level refers to the percentage of soybean meal, canola oil and, (in all treatments except Trt 6), synthetic lysine, methionine and threonine that were removed from the control rations and replaced with wheat. The percentage of whole wheat indicates the percentage of the final diet that was fed as whole grain.

TABLE 5. Average body weight (kg) in Trial A

Age (wks)	Treatment			Overall
	1	2	3	
0	.062	.062	.063	.062
3	.598	.604	.612	.604
6	2.384	2.392	2.384	2.387
9	5.576	5.647	5.625	5.616
12	9.009	9.160	9.014	9.061
16	13.328	13.445	13.232	13.335

TABLE 6. Feed to gain ratio in Trial A

Age (wks)	Treatment 1	2	3	Overall
Feed:gain - corrected for mortality				
3 to 6	1.477[a]	1.528[b]	1.545[b]	1.517
6 to 9	1.764	1.767	1.848	1.793
9 to 12	2.300[a]	2.272[a]	2.418[b]	2.330
12 to 16	3.030	3.172	3.142	3.115
3 to 16	2.279[a]	2.304[a]	2.372[b]	2.318
Feed:gain - not corrected for mortality				
3 to 16	2.464	2.525	2.566	2.518

TABLE 7. Overall incidence of mortality from 3 - 16 weeks of age (%) in Trial A

Category	Treatment 1	2	3	Overall
Cannibalism	0.0[b]	1.7[a]	0.0[b]	0.6
Spontaneous cardiomyopathy	1.8	3.9	1.1	2.3
Sudden death syndrome	1.2	0.0	0.6	0.6
Pendulous crop	2.9[a]	0.0[b]	2.3[a]	1.7
Other	1.7	2.2	2.3	2.1
Leg / skeletal problems	5.2	5.6	5.2	5.3
Total	12.8	13.4	11.4	12.5

TABLE 8. Average body weight (kg) in Trial B

Age (weeks)	Treatment 1	2	3	4	5	6	Overall
3	.590	.600	.608	.590	.594	.605	.598
6	2.422	2.357	2.356	2.432	2.439	2.367	2.396
9	5.622[a]	5.396[b]	5.331[b]	5.394[b]	5.427[b]	5.515[ab]	5.447
12	9.190[a]	8.695[b]	8.163[c]	8.611[b]	8.314[c]	8.849[b]	8.637
16	13.708[a]	12.758[bc]	11.711[d]	12.527[c]	11.814[d]	13.040[b]	12.593

[a-d] Mean values within a row with no common subscripts are significantly different ($P<0.05$).

TABLE 9. Feed to gain ratio in Trial B

Age (weeks)	Treatment						Overall
	1	2	3	4	5	6	
Feed:gain - corrected for mortality							
3 to 6	1.477^{cd}	1.573^{abc}	1.581^{ab}	1.464^{d}	1.490^{bcd}	1.609^{a}	1.532
6 to 9	1.775^{b}	1.945^{ab}	1.828^{b}	2.016^{a}	1.826^{b}	1.785^{b}	1.863
9 to 12	2.303^{d}	2.409^{c}	2.681^{a}	2.363^{cd}	2.550^{b}	2.495^{b}	2.467
12 to 16	2.979^{d}	3.254^{bc}	3.504^{a}	3.150^{c}	3.375^{ab}	3.219^{bc}	3.247
3 to 16	2.277^{c}	2.439^{b}	2.512^{a}	2.367^{b}	2.414^{b}	2.416^{b}	2.404
Feed:gain - not corrected for mortality							
3 to 16	2.384^{b}	2.541^{a}	2.662^{a}	2.535^{a}	2.556^{a}	2.552^{a}	2.539

$^{a-d}$ Mean values within a row with no common subscripts are significantly different ($P<0.05$).

TABLE 10. Carcass and meat yield in Trial B

Age (weeks)	Treatment						Overall
	1	2	3	4	5	6	
Yield as weighed (kg/bird)							
LW[1]	14.410[a]	13.531[b]	12.810[c]	13.449[b]	12.669[c]	13.992[ab]	13.477
EW[1]	11.273[a]	10.401[bc]	9.719[d]	10.240[c]	9.585[d]	10.758[b]	10.329
Yield as a percentage of live weight (%)							
EW	78.22[a]	76.78[b]	75.83[bc]	76.12[bc]	75.57[c]	76.88[b]	76.57
Yield as a percentage of eviscerated carcass (%)							
B meat[1]	22.72[a]	21.49[bc]	20.95[bc]	21.39[bc]	20.46[c]	21.78[ab]	21.46
B fillet	5.45[a]	5.22[abc]	5.17[bc]	5.37[ab]	5.17[bc]	5.13[c]	5.25
B skin	5.66	5.37	5.26	5.17	5.28	5.41	5.36
B total	28.17[a]	26.72[b]	26.12[bc]	26.77[b]	25.63[c]	26.90[b]	26.72
T meat[1]	13.44[ab]	13.67[ab]	13.36[b]	13.58[ab]	13.66[ab]	13.84[a]	13.59
T bone	1.80[c]	2.02[ab]	2.15[a]	2.06[a]	2.14[a]	1.93[b]	2.02
T skin	1.83	1.67	1.68	1.65	1.74	1.84	1.74
B & T Meat	41.61[a]	40.39[bc]	39.48[cd]	40.34[bc]	39.25[d]	40.79[ab]	40.31
Bone	8.25	8.75	8.95	8.85	9.00	8.84	8.77
Wings	11.56[c]	12.12[a]	12.36[a]	12.06[ab]	12.31[a]	11.69[bc]	12.02
Drums[1]	12.86[c]	13.67[ab]	13.94[a]	13.59[ab]	13.79[ab]	13.34[bc]	13.53
Keel	6.45	6.73	6.80	6.79	6.88	6.94	6.76
Rack	16.69	16.60	17.29	16.80	16.92	16.66	16.83
Ab fat[1]	1.05	.91	1.13	1.00	1.16	1.15	1.06

[a-d] Mean values within a row with no common subscripts are significantly different ($P<0.05$).

[1] LW – live weight; EW – eviscerated weight; B – breast; T – thigh; Drums – drumsticks; Ab fat – abdominal fat.

TABLE 11. Carcass and meat yield adjusted to common live body weight in Trial B

Age (weeks)	Treatment					
	1	2	3	4	5	6
Yield as weighed (kg/bird)						
EW[1]	10.539[a]	10.358[b]	10.244[b]	10.262[b]	10.221[b]	10.352[b]
Yield as a percentage of live weight (%)						
EW	78.05	76.77	75.95	76.12	75.71	76.79
Yield as a percentage of eviscerated carcass (%)						
B meat[1]	21.40	21.42	21.89	21.43	21.60	21.04
B fillet	5.53[a]	5.23[bc]	5.12[c]	5.37[ab]	5.10[c]	5.17[bc]
B skin	5.34	5.35	5.49	5.18	5.55	5.24
B total	26.93	26.64	27.01	26.80	26.70	26.22
T meat[1]	13.67	13.69	13.20	13.57	13.46	13.97
T bone	1.97	2.03	2.02	2.05	2.00	2.02
T skin	1.65	1.66	1.81	1.66	1.89	1.75
B & T Meat	40.60	40.33	40.20	40.37	40.13	40.23
Bone	8.61	8.77	8.69	8.83	8.69	9.04
Wings	12.05	12.15	12.01	12.04	11.89	11.96
Drums[1]	13.51	13.71	13.47	13.57	13.22	13.70
Keel	6.64	6.74	6.67	6.78	6.71	7.04
Rack	16.35	16.58	17.53	16.81	17.21	16.47
Ab fat[1]	0.95	0.90	1.19	1.01	1.24	1.10

[a-c] Mean values within a row with no common subscripts are significantly different ($P<0.05$)
[1] LW – live weight; EW – eviscerated weight; B – breast; T – thigh; Drums – drumsticks; Ab fat – abdominal fat.

TABLE 12. Overall incidence of mortality from 3 - 16 weeks (%) in Trial B

Age (weeks)	Treatment						
	1	2	3	4	5	6	Ov
Cannibalism	0.0	1.2	1.2	1.1	0.6	0.0	0.7
Arthritis	0.0	0.0	0.0	0.0	0.0	0.6	0.1
Spontaneous cardiomyopathy	1.7	0.0	1.1	2.8	1.2	0.0	1.3
Sudden death syndrome	0.0	0.6	0.6	0.0	1.1	0.6	0.5
Pendulous crop	0.6	0.6	0.6	1.2	0.6	1.1	0.8
Leg / skeletal problems	7.4	6.3	5.7	9.7	9.1	10.3	8.1
Other	1.2	0.6	2.3	2.2	0.0	1.1	1.2
Total mortality	10.8	9.1	11.4	17.0	12.5	13.8	12.4

TABLE 13. Economics of feeding turkeys whole wheat and diet dilution

Level	Market weight (kg/bird)	Feed consumed / kg shipped (kg/kg)	Poult + feed cost / kg shipped	
			Oct., 1991	Oct., 1995
Feeding pelleted feed or a mixture of pellets and a medium level of whole wheat (WW) (No dilution)				
Zero WW	12.298	2.426	$0.647	$0.818
Medium WW	13.445	2.462	$0.619	$0.792
Feeding pelleted feed or a mixture of pellets and a high level of whole wheat (No dilution)				
Zero WW	12.571	2.434	$0.644	$0.815
High WW	12.472	2.530	$0.626	$0.803
Economics of diluting turkey rations with pelleted wheat (Treatments 1, 4 & 5 in Trial B)				
Zero dilution	13.708	2.332	$0.636	$0.809
Medium dilution	12.527	2.450	$0.657	$0.837
High dilution	11.814	2.470	$0.650	$0.831

EXPERIMENT 3

FEEDING WHOLE BARLEY TO TURKEY TOMS

C.D. Bennett and H.L. Classen

ABSTRACT

This report details research on the use of whole barley in feeding programs for turkey tom flocks. The live performance to 96 d of age was compared for 1584 turkey toms fed diets with different levels of whole barley and insoluble grit (0 or 9 g/bird/wk). Four levels of whole grain were fed: i) 0%, ii) 5% at 0 d increasing to 35% by 19 d, iii) 5% at 0 d and increasing to 50% by 19 d, and iv) 5% at 19 d increasing to 50% by 40 d. All the diets had the same ingredient and nutrient specifications and differed only in feed form. Levels of whole barley in treatments i and iii were replicated with and without the use of grit; all other treatments had grit supplied. Final body weights for the four levels of whole barley, while also feeding grit, were 11.319, 10.907, 11.036 and 11.073 kg respectively, with the birds fed 35% whole grain by 19 d being significantly lighter than the controls. Feeding a high level of whole barley before 5 weeks of age had a negative effect on feed:gain ratio but once the gizzard had adjusted to a diet with 50% whole barley, feed:gain was unaffected or improved by feeding whole grain. Because early growth was slowed by feeding whole barley, the turkeys had fewer skeletal problems compared to the controls (2.0% vs 6.9%). Feeding insoluble grit had no effect on live performance. Feeding whole grain increased gizzard weight but supplying grit did not. Jejunal viscosity as well as pH of the crop, gizzard and duodenum were unaffected by feeding whole barley or grit. Whole barley can be successfully fed to commercial turkeys.

INTRODUCTION

Feeding whole wheat to poultry has become common in some regions of the world and considerable research suggests that chickens can adapt well to whole grain compared to pelleted grain (McIntosh *et al.*, 1962; O'Neil, 1964, Covasa and Forbes, 1994, Bennett *et al.*, 1995). The use of whole wheat in turkey diets also appears to be practical (Bennett *et al.*, unpublished data). Feeding whole grain reduces feed milling costs by avoiding the need to steam pellet a large portion of the ration and in some instances reduces trucking costs because the grain can be transported directly to the poultry farm instead of first being trucked to a feed mill for processing. While feeding whole grain has been beneficial in some regions, feeding whole barley has not been well investigated. If whole barley could be used in addition to whole wheat, then whole grain feeding programs would have greater flexibility.

In the present study, turkey toms were fed diets containing different levels of whole barley to determine at what ages and level whole barley could be used in turkey diets. The live performance of turkeys fed whole and pelleted barley was compared. The need to use grit

in whole grain feeding programs was investigated as well as the influence of whole grain and grit on organ weight, gut pH and gut viscosity.

MATERIALS AND METHODS

Day old male turkey poults (1584 Hybrid Large White) were randomly assigned to one of eight environmentally independent, light controlled rooms. Each room contained six pens (2.3 x 4 m), with 33 poults per pen or 198 per room. All poults were beak trimmed and injected with antibiotic at 0 d. A heat lamp was used in each pen to supplement the hot water pipe heaters until 12 d. After three d of constant light (24L:0D), all poults were exposed to an increasing lighting program: 3 - 5 d, 18L:6D; 5 - 7 d, 12L:12D; 7 - 19 d, 6L:18D; 19 - 26 d, 8L:16D; 26 - 32 d, 10L:14D; 32 - 40 d, 12L:12D; 40 - 47 d, 14L:10D; 47 - 54 d, 16L:8D; 54 - 96 d, 18L:6D. Light intensity, as measured by a an electronic luxmeter[1], was 20 lux from 0 - 19 d, 5 lux from 19 - 40 d and 1.5 lux from 40 - 96 d.

One pen in each room was assigned to one of six dietary treatments, providing 8 pens per diet over all the rooms. The rations varied in their content of whole barley (0 - 50%) and insoluble grit (0 or 9 g/bird/wk). In all dietary treatments, the birds were fed prestarter from 0 to 12 d, starter from 12 - 40 d, grower from 40 - 68 d and finisher from 69 - 96 d. The ingredient and nutrient specifications of the rations in all treatments were identical and only differed in feed form (Table 1). In Trt 1, the prestarter and starter were fed as crumbles, the grower and finisher were fed as pellets and insoluble grit was top dressed on the feeders. In Trt 2, the same rations were fed without any grit being supplied. In the remaining treatments, an increasing percentage of whole barley was included in the diet with the rest of ingredients being crumbles or pellets. The turkeys in Trt 3 were supplied grit and fed a diet containing 5% whole barley at 0 d and increasing to 35% by 19 d. In Trt 4, grit was also offered to the birds and the level of whole grain increased from 5% at 0 d to 50% at 19 d. Treatment 5 was identical to Trt 4 except that no grit was offered. Finally, the toms in Trt 6 were fed grit with the level of grain increasing from 5% at 19 d to 50% at 40 d.

Body weight gain (pen basis) and food consumption were measured for the time periods corresponding to the changes in whole grain levels. Any birds dying in the early brooding period were replaced at 12 d. All dead birds were weighed and examined for cause of death.

At 18 d and 32 d, 1 bird per pen or 8 birds per dietary treatment were killed with uthenal and the viscosity of the jejunal contents was determined. The weight of the crop, proventriculus, duodenum, ileum, jejunum and ceca was measured with digesta removed and the weight of the gizzard was determined with and without digesta. The pH of the crop, gizzard and duodenal contents was also measured. These same measurements were performed on birds reared in a spare room, eight of them fed the same rations as Trt 1 but without any feed enzyme and another eight fed the same rations as Trt 4 but again without feed enzymes.

Statistical analyses were computed using SAS Institute (1990) and where appropriate, means were separated using Duncan's Multiple Range Test. Differences were considered significant when $P<0.05$. Pre-planned contrasts were used to compare Trts 1 and 2 as well as Trts 4 and 5 to determine the effect of supplying insoluble grit at the same level of whole barley.

RESULTS AND DISCUSSION

The effects of dietary treatment on body weight and body weight gain are shown in Tables 2 and 3. At 33 d and 40d, the birds in Trts 1 and 2 that had been fed the control rations, with and without grit, were significantly heavier than any of the treatments where more than 5% whole barley had been fed (Trts 3, 4 and 5). The birds in Trt 6, which had been fed only the 5% whole grain from 19d, were significantly heavier than those in Trt 3 which had been fed 35% whole grain by 19 d. The toms in Trt 6, when fed 20% whole barley from 33 to 40 weeks of age had a similar body weight gain to the toms fed the pelleted diets. Delaying the first exposure of the birds to whole grain until 19 d was beneficial for growth rate.

The body weight gain of all birds fed whole grain was depressed from 40d to 68d, possibly due to an inability of the gizzard to process high levels of whole grain fast enough to maintain growth. Growth rates recovered by 68d to 96d and body weight gain was the same for toms fed pellets or whole grain. The final market weights at 96d were similar for birds fed pellets (Trts 1 and 2) or 50% whole barley and grit (Trts 4 and 6). The birds in Trts 3 and 5, however, had lower market weights. Once the gizzard was conditioned to the whole grain, the body weight gain matched that of the birds fed pellets but the birds could not always catch up the early loss in growth. Delaying the introduction of whole grain minimised the early depression in growth and produced market weights similar to those of turkeys fed pellets.

Feeding whole barley at early ages had a negative effect on gain:feed (Table 4). From 19d to 33d, the birds in Trts 3, 4 and 5 were fed 35% to 50% whole barley and had a lower gain:feed than those fed the control rations (Trts 1 and 2). The turkeys in Trt 6 were fed only 5% whole grain during this period and had a gain:feed similar to that of the birds fed the control ration without grit (Trt 2) but less than that of the birds fed the control ration plus grit (Trt 1). From 68 - 96d, the trend was reversed with the turkeys in Trt 4 having a superior feed efficiency to those in Trts 1 and 2 and the birds in Trt 3 having a better gain:feed than those in Trt 2. While age affected the efficiency with which whole grain was used, supplying or not supplying insoluble grit had no influence on gain:feed. When the performance of turkeys fed similar levels of whole barley is compared, no differences were observed at any age (Trt 1 vs 2; Trt 4 vs 5). Overall, gain:feed from hatch to market was not influenced by feeding whole grain, likely due to the gizzard adjusting to processing the grain as the turkeys aged and the better liveability of the turkeys feed whole barley (see below).

When gain:feed was corrected for mortality (Table 5) by adding the weight of the dead

birds to the body weight gain, the feed efficiency advantage of feeding whole barley after 68 d of age disappeared. The improvement in bird health, not a superior digestive process, was responsible for the improved feed efficiency when whole barley was fed at later ages.

The mortality of the turkeys on the different treatments is displayed in Table 6. Compared to the birds fed the control rations (Trts 1 and 2), feeding a high level of whole grain from an early age (Trts 4 and 5) significantly reduced total mortality. The toms in Trts 3 and 4 had significantly fewer leg and skeletal problems than the birds fed the completely pelleted diets. The slower early growth rate of the birds in these treatments may explain their improved health.

At 18 d, feeding whole grain and/or grit had no effect on organ weight or the pH or viscosity of the digesta (Table 7). By 32 d, feeding more than 5% whole grain increased gizzard weight (Trts 3, 4 and 5) but supplying grit did not (Table 8). The pH and viscosity of the gut contents at 32 d was unaffected by feeding whole grain or grit. The viscosity of the diets without enzyme was not high.

CONCLUSIONS

1. If whole barley is introduced gradually after 3 weeks of age, turkeys can be fed a diet of 50% whole barley plus supplement and will have the same market weight and feed efficiency as birds fed pelleted diets.
2. Feeding high levels of whole barley at an early age can slow early growth and decrease feed efficiency in the brooding period but the slower growth will result in fewer leg problems and improved liveability.
3. Insoluble grit is not necessary for turkeys to digest whole barley but may provide a slight increase in growth rate in some circumstances.

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TABLE 1. Dietary treatments - % of whole barley in rations

Age, d	Treatment[1]					
	1	2	3	4	5	6
0-12	0	0	5	5	5	0
12-19	0	0	20	20	20	0
19-33	0	0	35	50	50	5
33-40	0	0	35	50	50	20
40-96	0	0	35	50	50	50

[1] Trt 1 - Control, grit; 2 - control, no grit; 3 - grit and low whole barley; 4 - grit and high whole barley; 5 - no grit and high whole barley; 6 - grit and high whole barley at later age.

TABLE 2. Effect of diet on body weight (kg)

Age (d)	Treatment[1]						
	1	2	3	4	5	6	SEM[2]
12	0.283	0.288	0.279	0.282	0.28	0.284	0.003
19	0.48	0.475	0.461	0.465	0.469	0.482	0.006
33	1.443^{a}	1.414^{a}	1.315^{c}	1.334^{bc}	1.343^{bc}	1.393^{ab}	0.02
40	2.229^{a}	2.179^{a}	1.998^{c}	2.063^{bc}	2.068^{bc}	2.146^{ab}	0.028
68	6.838^{a}	6.808^{ab}	6.313^{d}	6.510^{cd}	6.433^{cd}	6.610^{bc}	0.069
96	11.291^{a}	11.319^{a}	10.907^{b}	11.036^{ab}	10.794^{b}	11.073^{ab}	0.115

[1] Trt 1 - Control, grit; 2 - Control, no grit; 3 - Grit and low whole barley; 4 - Grit and high whole barley; 5 - No grit and high whole barley; 6 - Grit and high whole barley at later age.
[2] Standard error of the mean.
[a-c] Means values within a row with no common superscripts are significantly different ($P<.05$).

TABLE 3. Effect of diet on body weight gain (kg)

	Treatment[1]						
Age (d)	1	2	3	4	5	6	SEM[2]
0-12	0.232	0.237	0.228	0.231	0.23	0.233	0.003
12-19d	0.197	0.182	0.182	0.183	0.19	0.198	0.005
19-33	0.963[a]	0.938[ab]	0.855[d]	0.869[cd]	0.874[cd]	0.911[bc]	0.016
33-40	0.786[a]	0.765[a]	0.682[c]	0.729[b]	0.725[b]	0.753[ab]	0.011
40-68	4.610[a]	4.629[a]	4.315[b]	4.447[b]	4.365[b]	4.464[b]	0.048
68-96	4.452	4.512	4.594	4.526	4.361	4.463	0.079
0-96	11.239[a]	11.268[a]	10.856[b]	10.985[ab]	10.743[b]	11.023[ab]	0.115

[1] Trt 1 - Control, grit; 2 - Control, no grit; 3 - Grit and low whole barley; 4 - Grit and high whole barley; 5 - No grit and high whole barley; 6 - Grit and high whole barley at later age.
[2] Standard error of the mean.
[a-d] Means values within a row with no common superscripts are significantly different (P<.05).

TABLE 4. Effect of diet on gain to feed efficiency

	Treatment[1]						
Age (d)	1	2	3	4	5	6	SEM[2]
0-12	0.698	0.697	0.681	0.692	0.685	0.692	0.011
12-19	0.658	0.580	0.612	0.605	0.608	0.610	0.021
19-33	0.684[a]	0.666[ab]	0.635[c]	0.613[cd]	0.630[cd]	0.650[bc]	0.007
33-40	0.623	0.613	0.630	0.630	0.627	0.626	0.009
40-68	0.533	0.534	0.548	0.551	0.543	0.532	0.007
68-96	0.326[bc]	0.314[c]	0.351[ab]	0.366[a]	0.342[abc]	0.333[abc]	0.011
0-96	0.449	0.443	0.460	0.467	0.453	0.449	0.006

[1] Trt 1 - Control, grit; 2 - Control, no grit; 3 - Grit and low whole barley; 4 - Grit and high whole barley; 5 - No grit and high whole barley; 6 - Grit and high whole barley at later age.
[2] Standard error of the mean.
[a-d] Means values within a row with no common superscripts are significantly different (P<.05).

TABLE 5. Effect of diet on gain to feed efficiency (mortality corrected)

Age (d)	Treatment[1]						SEM[2]
	1	2	3	4	5	6	
0-12	0.704	0.71	0.694	0.702	0.699	0.702	0.008
12-19	0.716	0.637	0.666	0.657	0.667	0.668	0.019
19-33	0.718^{a}	0.702^{ab}	0.671^{cd}	0.655^{d}	0.665^{cd}	0.685^{bc}	0.007
33-40	0.623	0.620	0.630	0.630	0.629	0.626	0.008
40-68	0.556^{ab}	0.559^{ab}	0.564^{b}	0.556^{ab}	0.552^{b}	0.550^{a}	0.003
68-96	0.366	0.372	0.380	0.377	0.366	0.370	0.004
0-96	0.480^{ab}	0.483^{a}	0.482^{a}	0.477^{ab}	0.472^{b}	0.477^{ab}	0.003

[1] Trt 1 - Control, grit; 2 - Control, no grit; 3 - Grit and low whole barley; 4 - Grit and high whole barley; 5 - No grit and high whole barley; 6 - Grit and high whole barley at later age.
[2] Standard error of the mean.
[a-d] Means values within a row with no common superscripts are significantly different ($P<.05$).

TABLE 6. Effect of diet on cause of mortality

Age (d)	Treatment[1]						SEM[2]
	1	2	3	4	5	6	
Cannibalism	0.40	0.81	0.00	0.00	0.00	0.00	0.291
Early Death[3]	0.00	0.00	0.00	0.40	0.00	0.00	0.165
Infectious[4]	0.40	0.00	0.00	0.00	0.00	0.40	0.208
Sudden death syndrome	0.40	0.40	0.00	0.00	0.40	0.40	0.318
Pendulous crop	0.40	1.21	0.40	0.40	0.40	0.81	0.387
Leg and bone[5]	6.86^{ab}	8.47^{a}	4.03^{bc}	2.02^{c}	4.84^{abc}	4.84^{abc}	1.370
Miscelaneous[6]	0.40	1.21	2.42	0.81	0.40	1.61	0.623
Total Mortality	8.87^{ab}	12.10^{a}	6.86^{ab}	3.63^{b}	6.05^{b}	8.07^{ab}	1.811

[1] Trt 1 - Control, grit; 2 - Control, no grit; 3 - Grit and low whole barley; 4 - Grit and high whole barley; 5 - No grit and high whole barley; 6 - Grit and high whole barley at later age.
[2] Standard error of the mean.
[3] Early death includes drown, dehydration, starveout, yolk sac infection, inflamed navel.
[4] Infectious mortality includes airsacculitis, pericarditis and enteritis.
[5] Leg-bone includes valgus - varus, rotated tibia, crooked toes and broken bones.
[6] Miscellaneous includes NVL, round heart, intestinal accident, missing, aspergillus and haemorrhages.
[a-c] Means values within a row with no common superscripts are significantly different ($P<.05$).

TABLE 7. Effect of diet on organ weight (g), gut pH and digesta supernatant viscosity (cps) at 18d

	Treatment								
Weight/pH/viscosity	1	2	3	4	5	6	7	8	9
Body weight	438.8	461.0	451.1	444.8	451.5	496.5	435.1	388.3	N/A
Crop	2.8	2.7	2.5	2.4	2.5	2.7	2.6	2.6	N/A
Proventriculus	2.5	2.3	2.1	2.3	2.5	2.6	2.1	2.1	N/A
Empty gizzard	13.3	13.3	13.3	14.7	14.7	14.0	12.7	13.4	N/A
Gizzard+digesta	22.1	21	22.8	24.4	23.7	23.3	22.4	21.9	N/A
Duodenum	3.0	3.5	2.9	3.4	3.0	3.4	3.1	2.5	N/A
Jejunum	5.7	5.8	6.0	5.6	5.2	6.2	4.8	5.1	N/A
Ileum	4.1	4.0	4.1	4.1	4.0	4.5	4.0	4.0	N/A
Ceca	2.7	2.6	2.6	2.7	2.6	2.6	2.5	2.9	N/A
Crop pH	5.3	5.4	5.3	5.5	5.5	5.3	5.4	5.6	N/A
Gizzard pH	3.1	3.5	3.0	2.9	3.1	3.8	2.9	3.3	N/A
Duodenum pH									N/A
Jejunal viscosity	4.0	3.8	4.9	4.0	4.8	3.6	6.2	3.6	N/A

Note: Treatment 7 = Birds fed same feed as Treatment 1 except that no feed enzymes were added. Treatment 8 = Birds fed same feed as Treatment 4 except that no feed enzymes were added. Treatment 9 = Birds fed same as Treatment 1 were given ground barley as sole feed the day before the viscosity test was performed.

TABLE 8. Effect of diet on organ weight (g), gut pH and digesta supernatant viscosity (cps) at 32d

Weight/pH/viscosity	Treatment								
	1	2	3	4	5	6	7	8	9
Body weight	1354.1	1421.0	1311.1	1354.6	1270.6	1402.6	1237.1	1125.1	1211.3
Crop	6.4	5.9	6.2	6.4	5.7	6.0	6.5	5.6	6.4
Proventriculus	4.9	5.3	5.1	5.2	5.1	5.2	5.1	4.5	4.3
Empty gizzard	34.7	34.5	40.7	43.5	42.1	33.8	35.0	37.7	33.6
Gizzard+digesta	52.7	47.9	60.5	67.1	58.4	50.8	54.3	58.1	45.3
Duodenum	7.1	6.8	6.4	7.8	6.3	6.8	6.0	6.9	6.4
Jejunum	12.9	14.5	15.1	15.5	14.4	15.0	12.1	13.6	12.6
Ileum	9.2	10.1	10.4	10.9	9.8	0.3	8.8	10.4	10.4
Ceca	6.4	6.9	5.7	6.2	6.2	6.7	6.0	5.6	6.9
Crop pH	5.5	5.5	5.3	5.2	5.5	5.4	5.3	5.4	5.4
Gizzard pH	4.6	4.0	4.3	4.2	3.9	3.8	3.9	3.5	2.7
Duodenum pH	5.5	5.6	5.6	5.8	5.8	5.7	5.8	5.7	5.9
Jejunal viscosity	2.8	3.4	3.6	3.6	3.3	3.1	3.6	5.8	38.3

Note: Treatment 7 = Birds fed same feed as Treatment 1 except that no feed enzymes were added. Treatment 8 = Birds fed same feed as Treatment 4 except that no feed enzymes were added. Treatment 9 = Birds fed same as Treatment 1 were given ground barley as sole feed the day before the viscosity test was performed.

EXPERIMENT 4

FEEDING WHOLE WHEAT AND BARLEY TO BROILER CHICKENS

C. D. Bennett and H.L. Classen

ABSTRACT

Studies were conducted to determine the impact of grain texture (whole, mash or crumbled/pelleted) on the performance of broiler chickens. Another research objective was to examine the rate at which whole grain can be increased during the broiler life cycle. Both wheat and barley were utilised in this research. The major findings were as follows:

1. Broiler chickens can be introduced to 5% whole wheat or barley at day of hatch with no negative effects on growth or feed efficiency.
2. Time is required for broiler chickens to adjust to high levels of whole grain. Because of the young age at which broilers are marketed, the birds do not have time to fully adjust to whole grain. The resulting loss in growth rate and feed efficiency will limit the level of whole grain which can be economically fed.
3. The economics depends on how milling charges are applied to the mash or pelleted supplements and how economically a chicken grower can purchase locally grown grain.
4. The main influence of feeding mash supplements is to slow early growth rate. Birds adjust more rapidly to mash diets. If on-farm mixing of high levels of grain is desired, hammer milled wheat or barley can be used with a minimum of loss in performance.
5. Carcass yield is not affected by feeding mash or whole grain.

INTRODUCTION

Handling, trucking and processing adds significantly to the cost of the grain used in poultry rations. Most commercial feed mills buy 70% to 100% of their grain from elevators or brokers and direct purchases of wheat or barley from grain farmers comprise a limited amount of the total grain used in poultry rations on the Prairies. The elevator handling fee of $10 to $15/tonne of grain can add $5 to $10/tonne to the final cost of the feed. Once it is purchased from the elevator, a commercial feed mill will grind and pellet the grain; the pelleting process adds approximately $5/tonne to the cost of the complete feed or another $3/tonne to the grain portion of the diet. Once processed, the feed is trucked to the poultry farm, commonly costing $15/tonne of complete feed, and adding another $10 to the cost of the grain portion of the diet. The total handling, processing and trucking cost associated with the grain portion of poultry feed is estimated to be $18 to $23/tonne of complete feed. Depending on the year, these charges account for 6 to 10% of the total feed cost.

Purchasing whole grain locally provides broiler chicken growers the opportunity to reduce the milling charges associated with the grain portion of their feed. If grain is purchased from a neighbouring grain farm, much of the elevation, trucking and processing charges can be avoided. The economic benefit from adding whole grain on-farm, however, is dependent on how the performance of broiler flocks fed whole grain compares to that of flocks fed completely pelleted or mash diets.

In the present research, the effect of grain texture (whole, mash, or crumbled/pelleted) on the growth rate, feed conversion, mortality and carcass yield of broiler chickens was determined. The rate at which whole grain could be increased in the feed during a broiler cycle was also examined. Because wheat or barley can be used economically on the Prairies, both whole wheat and whole barley were tested.

METHODS AND MATERIALS

Trial 1

A total of 2,256 broiler cockerels were housed in 4 environmentally controlled rooms, with 12 pens per room and 47 chicks in each of the 2.3 x 2 m pens. The birds were reared under an increasing lighting program. All birds received starter ration from 0 to 13 days of age, grower ration from 13 to 27 days and finisher ration from 27 to 48 days (Table 1). The trial was designed as a 6 x 2 factorial with 6 levels of whole grain and 2 forms of supplement (Table 2). The ingredient composition of the diets was identical for all treatments, with the only differences being in the proportion of the diet that was fed as whole wheat and whether the non-whole wheat portion of the diet was fed as crumbles/pellets or ground mash. Six regimes of feeding whole grain were used: 1) 0% whole grain from 0 to 48 days, 2) 0% whole grain at 0 days, 5% at 6 days, 20% at 13 days, 35% at 27 days, 3) 0% whole grain at 0 days, 5% at 6 days, 35% at 13 days, 50% at 27 days, 4) 5% whole grain at 0 days, 20% at 6 days, 35% at 13 days, 50% at 27 days, 5) 0% whole grain at 0 days, 5% at 6 days, 50% at 13 days, 65% at 27 days and 6) 5% at 0 days, 20% at 6 days, 50% at 13 days, 65% at 27 days. Each of the 6 levels of whole wheat was replicated using both crumbled/pelleted and mash supplements. For the treatments using steam-pelleted supplements, the non-whole grain portion of the diet was fed as a crumble in the starter and grower and a pellet in the finisher. When mash supplements were used, the grain portion of the diet was coarsely ground using a hammermill with a 0.64 cm screen. No insoluble grit was supplied in any of the treatments.

The birds were pen weighed at 0, 6, 13, 27 and 48 days of age and feed consumption was determined for each of these time periods. Sixteen birds per treatment, 4 bird per pen, were selected at 41 days of age, weighed, fasted overnight and then processed at 42 days of age to determine carcass yield and weight of internal organs. For the selected birds, the eviscerated carcass, offal, crop, proventiculus, gizzard (both with and without digesta contents), small intestine and abdominal fat pad were weighed. All weights were expressed as a percentage of live body weight. All birds dying during the trial were weighed and necropsied. The feed:gain was corrected for mortality by including the weight of the dead birds in the body weight gain.

Samples of each diet were sieved with 3.3 mm, 1.7 mm and 1.0 mm sieves to determine the distribution of particle size. Most of the whole wheat would pass through the 3.3 mm screen and be caught by the 1.7 mm screen. Most pellet-sized particles would be caught in the 3.3 mm screen and crumble sized particles in the 1.7 mm screen. Any material passing through the 1.0 mm screen was very powdery and was considered to be fines.

Trial 2

A total of 2,208 broiler cockerels were housed and reared similarly to Trial 1 except that 46 chicks were placed per pen in each of the 12 pens in 4 rooms. All birds received barley based starter ration from 0 to 14 days of age, grower ration from 14 to 28 days and finisher ration from 28 to 49 days (Table 1). As in the previous trial, Trial 2 was designed as a 6 x 2 factorial with 6 levels of whole grain and 2 forms of supplement (Table 2). The same 6 whole grain feeding regimes were used as in Trial 1 except that whole barley was fed instead of whole wheat and the whole grain levels were changed at one day of age later than Trial 1. The steam pelleted and mash supplements were produced in a manner and form similar to Trial 1. No insoluble grit was supplied.

The birds were pen weighed at 0, 7, 14, 28, and 49 days of age and feed consumption was determined for each of these time periods. All birds dying during the trial were weighed and necropsied. The feed:gain was corrected for mortality by including the weight of the dead birds in the body weight gain.

Samples of each diet were sieved with 3.3 mm, 1.7 mm and 1.0 mm screens to determine the distribution of particle size. Unlike the whole wheat diets, a considerable amount of the whole barley would be caught in the 3.3 mm screen because of the barley grains were longer.

Both trials were analysed as 6 x 2 factorial designs using level of whole grain and form of supplement as main effects. SAS (1990) was used for analysis of variance and when significant, the Duncan's multiple range test was used to separate the means. Differences between treatment means were considered statistically significant at $P<0.05$.

RESULTS

Trial 1

Birds fed mash supplements had a lower body weight gain than those fed steam pelleted supplements at all ages and cumulatively over the life of the flock (Table 3). Feeding 5% whole wheat from 0 to 7 days had no influence on weight gain but feeding whole wheat did affect weight gain from 6 to 27 days of age, depending on the type of supplement used. At 6 to 13 days of age, the birds fed 20% whole wheat (levels 4 and 6), combined with a pelleted supplement grew slower than birds fed a lower level of whole grain and pelleted supplement. Feeding whole wheat did not decrease body weight gain when mixed with a mash supplement. At 13 to 27 days of age, a similar interaction occurred; the birds fed a pelleted supplement and 35% to 50% whole wheat, (levels 4, 5 and 6), gained less weight than birds reared on lower levels of whole grain. Unlike 6 to 13 days of age, however, the birds fed 20% whole grain grew at a rate similar to those fed just pellets. No differences due to whole grain level were observed for the broilers fed mash based diets. From 27 to 48 days of age, feeding 35% to 65% whole wheat had no affect on body weight gain, regardless of the type of supplement used. Total body weight gain was unaffected by feeding whole wheat.

Feeding a mash supplement increased feed:gain from 6 to 27 days, had no effect from 27

to 48 days and increased cumulative feed:gain marginally compared to a pelleted supplement (2.06 vs 2.03; Table 4). Broilers fed 0% or 5% whole wheat from 0 to 6 days had similar feed conversions. Feeding 20% whole wheat from 6 to 13 days of age increased feed:gain compared to the feeding no whole wheat. At 13 to 27 days of age, the broilers were fed grower rations with 20% to 50% whole wheat and feed:gain was increased compared to the birds fed the control diets. Birds fed 65% whole wheat in the finisher, had a higher feed:gain from 27 to 48 days than birds fed finishers containing 0% or 35% whole wheat. The broilers fed 35% whole wheat and some of those fed 50% whole wheat, (levels 2 and 4), had a feed:gain similar to the birds fed no whole wheat. Feed:gain for the life of the flock was lower for birds reared on the control rations than any of those reared on whole grain diets. Broilers fed the highest two levels of whole wheat had a higher cumulative feed:gain than most of the other treatments.

Feeding a mash supplement reduced mortality due to sudden death syndrome, increased skeletal/leg problems but did not change total mortality (Table 5). Similarly, feeding almost any amount of whole wheat, (levels 2, 3, 4 and 6), reduced skeletal/leg problems compared to not feeding any whole grain, (level 1), but did not change total mortality. Sudden death syndrome and skeletal/leg problems accounted for approximately two thirds of the mortality in the trial.

Feeding mash supplements resulted in a small but significant increase in the weight of the gizzard, both with and without digesta contents, as a percentage of the live weight of the bird (Table 6). Eviscerated carcass yield and the percentage weight of other organs were unaffected by feeding mash supplements. Feeding some levels of whole wheat, (levels 3, 4 and 5), increased the percentage of offal compared to not feeding any whole wheat but did not alter eviscerated carcass yield. Feeding whole wheat had no overall effect on percent proventriculus but some small, inconsistent differences occurred between birds fed the same type of supplement, (significant whole wheat level * supplement form interaction). Crop, small intestine and abdominal fat pad weights were unaffected by whole grain level or form of supplement.

The most noticeable dietary effects on organ weight were observed in the response of gizzard weight to different levels of whole grain. Cockerels fed no whole wheat, (level 1), had the smallest gizzards and those never fed more than 35% whole wheat, (level 2), had gizzards smaller than birds fed higher levels of whole grain. A significant interaction indicated that type of supplement influenced the effect of whole grain on gizzard size but the effect was fundamentally the same for both mash and pelleted supplements. Regardless of the type of supplement used, the birds on the control rations had lower gizzard weights than all birds fed whole wheat or all but birds fed a low amount of whole wheat, (level 2). For both types of supplement, the birds fed the 2nd level of whole wheat had lower gizzard weights than most or all of the birds fed higher levels of whole wheat. Overall, the progressive increase in gizzard weight caused by feeding higher levels of whole wheat appeared to be most noticeable for the weight of the gizzard minus digesta compared to the weight plus digesta. Numerically, the differences in gizzard weight accounted for most of the differences in eviscerated carcass yield between the birds fed different levels of whole grain.

Trial 2

As in Trial 1, feeding a mash supplement decreased body weight gain in all time periods and reduced total body weight gain compared to a pelleted supplement (Table 7). Feeding whole barley decreased body weight gain overall and in many time periods. From 0 to 7 days of age, however, the response to whole barley appeared to be positive and the broilers fed 5% whole barley plus a pelleted supplement, (levels 4 and 6), had a greater weight gain than some of the birds fed no whole barley at that age, (levels 2, 3 and 5). Body weight gain was similar for cockerels fed different levels of whole barley in combination with mash supplements. No differences due to whole barley level were observed at 7 to 14 days of age, even though some of the birds were fed 20% whole grain during this time. From 14 to 28 days of age, feeding 0 to 50% whole barley had no overall effect on weight gain but the birds fed a pelleted supplement and 50% whole barley (level 5) had a lower body weight gain than the other birds fed pelleted supplements. From 28 to 49 days of age, all of the cockerels, even those fed 35% whole barley, grew slower than those fed the control diets and the decrease occurred with both mash and pelleted supplements. Total body weight gain was reduced for birds fed all levels of whole barley except for those fed the maximum level of whole barley, (level 6).

Feed:gain was similar at all ages and in total for birds fed both mash and pelleted supplements. Feeding 5% whole barley from 0 to 7 days of age, (levels 4 and 6), improved in feed conversion compared to several of the treatments where no whole grain was fed (levels 2, 3 and 5); this pattern was identical to the one observed for body weight gain at the same age. From 7 to 14 days of age, feeding 5% to 20% whole barley had no impact on feed conversion but at 14 to 28 days of age most of the birds fed 20% to 50% whole barley, (levels 2, 4, 5 and 6), had a higher feed:gain than the birds on the control rations. The utilisation of whole barley diets improved by 28 to 49 days of age, although the improvement in feed:gain was most noticeable with mash supplements. Feeding 35 to 65% whole barley mixed with a mash supplement resulted in a feed:gain similar to that of a mash finisher with no whole grain, the only exception being at the 4th level of whole barley. For broilers fed pellet based finisher, the birds fed 35% whole barley (level 2) and some of those fed 50 to 65% whole barley at (levels 3 and 5) had a feed conversion similar to birds fed the pelleted control ration. Some of the birds fed 65% whole barley and pelleted supplement, (level 6), had a higher feed:gain than those fed 35% whole barley, (level 2). The response of cumulative feed:gain to whole grain feeding, for broilers fed mash supplements, was identical to that observed in the finisher stage; only the broilers in the 4th level of whole barley had a higher cumulative feed:gain than the birds fed just mash. For cockerels fed pelleted supplements, the birds fed a low level of whole grain, (level 2), had the same cumulative feed:gain as the control birds but all other birds fed whole barley had a higher feed:gain for the life of the flock. The broilers fed the maximum amount of whole barley, (level 6), had a higher cumulative feed:gain than those fed the 2nd level.

Mortality due to ascites and right heart failure was reduced by feeding a mash supplement but total mortality was unaffected. Feeding whole barley did not affect cause of mortality or total mortality. As in Trial 1, approximately two thirds of the mortality was due to acute death syndrome and skeletal/leg problems.

DISCUSSION

Feeding a mash supplement had similar effects with both wheat and barley based diets. The major impact of feeding a mash supplement was to slow early growth rate compared to birds fed steam pelleted supplements. While body weight gain was reduced at all ages in both trials, gain was reduced by an average of 9% in the first week but only 2% from 4 to 7 weeks of age. Slower growth rate on mash based diets has been noted previously.

While steam pelleting improved growth rate, it had almost no effect on feed efficiency. In most time periods, the feed:gain of broilers fed wheat or barley mash supplements was very similar to those fed pelleted supplements. Indeed, broilers fed a wheat mash supplement had a lower feed:gain ratio at 6 to 27 days of age than those fed a pelleted supplement. While cumulative feed:gain was higher for cockerels fed a wheat mash supplement, the difference was small and averaged over the two trials, the cumulative feed:gain was almost identical for birds fed mash and pelleted supplements (2.192 vs 2.193).

The major difference between the two forms of supplements may have been the high level of fines found in the mash diets. Sieving the diets demonstrated that a mash diet with no whole grain would 35% to 40% fines while a mixture of 65% whole grain and 35% mash supplement contained 17% fines on average. The level of fines in the crumbled and pelleted diets ranged from 2% to 15%.. Previous research has demonstrated a reduction in growth in birds fed diets with 30% or more fines. Young broilers may have been unable to consume the fine particles in mash feed as quickly as the larger particles in a crumbled starter or grower. At later ages, the cockerels fed mash supplements had a growth rate and feed:gain ratio almost identical to those fed pellets; the birds were able to consume and utilise mash feed as efficiently as pelleted feed.

The broiler chickens did not adjust as readily to the whole grain as to mash supplements and the response was influenced by whether whole wheat or barley was fed. Broiler cockerels could be fed either 5% whole wheat or barley at day of hatch without any negative effects on growth rate or feed efficiency. When 20% whole grain was introduced after the first week, birds fed whole wheat and pellets could not maintain the same growth as birds just fed pellets but those fed whole barley could. Perhaps the slower growth rate of birds in Trial 2, allowed those fed whole barley to more readily attain the same growth rate as the controls. As whole grain was increased to 35% or more, some loss in growth rate was observed with both wheat and barley. The loss was least noticeable with mash based diets, indicating that the gizzard can process whole grain fast enough to match the growth rate of birds fed just mash. No loss in growth rate was ever observed in cockerels fed whole wheat plus mash supplement compared to those fed only mash; the birds fed whole barley plus mash grew comparably well on rations containing 50% whole grain up to 4 weeks of age but fell behind afterwards. Birds fed high levels of whole grain plus pelleted supplements had difficulty matching the rapid growth rate of birds fed just pellets. Feeding 35% to 50% whole wheat and 50% whole barley reduced growth rate from 2 to 4 weeks of age compared to feeding just pellets. The broilers fed whole wheat adjusted and from 4 to 7 weeks of age had the same growth rate as birds fed pellets. Birds fed whole barley, however, could not achieve the growth rate of birds fed pellets during this time period when broiler growth rate would be at its maximum. Overall, broiler gizzards could process whole grain fast enough to attain the same growth as birds fed mash but did not, at least in the

first 7 weeks, grow as fast as birds fed pellets. Previous research with turkeys would suggest that if the birds were maintained on whole grain after 7 weeks of age they would be able to match the growth rate of birds on pellets at later ages.

In general, the feed:gain of broilers was affected less by feeding whole grain, especially whole barley, than was growth rate. Cockerels were fed 5% whole wheat or barley at day of hatch with no loss in feed efficiency. For barley based diets, broilers fed 35% whole grain never displayed an increase in feed:gain compared to birds fed no whole barley, (although those fed 20% whole barley had an increased feed:gain at 2 to 4 weeks). By 4 to 7 weeks of age, birds in some the treatments where 50% to 65% whole barley was fed had the same feed:gain as birds fed the control rations. When first introduced to 20, 35, 50 or 65% whole wheat, however, all broilers displayed an increase in feed:gain. By 4 to 7 weeks of age, the birds fed 35% whole wheat and some of those fed 50% whole wheat had the same feed conversion as birds fed no whole grain. For both wheat and barley, the effect of feeding whole grain on feed conversion was similar for both mash and pelleted supplements. Broilers can utilise mash and pelleted grain with about the same efficiency but, at least a young ages, cannot use whole grain as efficiently as either form.

Both mash and whole grain feeds did affect broiler performance but one benefit was a reduction in metabolic disease. Significant reductions in acute death syndrome, ascites/right heart failure on mash feed as well as skeletal/leg problems on whole grain feed were observed. Inexplicably, skeletal/leg problems were increased with mash feeding in Trial 1. These diseases have been related to rapid early growth rate and the slower growth with mash and whole grain feed may explain some of the improvement in health. Previous research with turkeys has demonstrated a reduction in leg/skeleton and heart problems in birds fed whole grain.

Feeding mash or whole grain did not have a negative effect on carcass yield or the weight of most of the digestive tract organs. Feeding whole grain, however, did cause a significant increase in gizzard weight with progressive increases in gizzard size from zero to low to higher levels of whole grain. The need increase gizzard weight in response to whole grain may explain the adjustment period observed in growth rate and feed:gain as birds were introduced to higher levels of whole grain.

ECONOMICS

The chick and feed costs were calculated for the broilers reared in the different treatments using feed ingredient costs from August, 1997 (Tables 12 and 13). Chicks were valued at $0.50 each to calculate the chick cost/kg shipped. The cost of trucking the wheat or barley from a grain farm to a chicken farm or a feed mill was assumed to be the same and as a result was not a consideration in these calculations. Feed processing costs were based on $5 to pellet a tonne of complete feed or supplement and another $15/tonne to be trucked from the mill to the farm. It was assumed that since whole grain would not be pelleted or trucked from the mill to the farm, pelleting and trucking costs would not be charged for whole grain added on the farm. The total trucking and milling charges, as well as the cumulative whole grain usage, for each feeding program are displayed in Tables 14 and 15.

The milling charges, other than pelleting and trucking, were calculated for two scenarios:

1. A constant charge of $25/tonne was used for both complete feed and a supplement.
2. The mark up on the supplement was increased as the level of whole grain added in the diet was increased.

The first scenario reflected the situation in an integrated poultry company or producer owned feed mill in which the feed mill was running at capacity. The second scenario was more reflective of that in an independent poultry industry in which feed companies would need to increase their margins to maintain profitability as they changed from producing complete feed to supplement. Under the second scenario, other milling charges would increase from $25/tonne of complete feed to $50/tonne of a supplement designed to be mixed 50:50 with whole barley. In this situation, the mark up earned by a feed mill, above pelleting and trucking costs, would be the same from a flock of broilers fed complete feed or whole grain and supplement.

Under the first scenario of an integrated poultry company, feed plus chick costs would be reduced the most by feeding programs which reached maximums of 50% to 65% whole wheat or barley. The cost reduction would range from 0.7 to 5.6 cents/kg shipped for the broilers reared on the higher levels of whole grain and a pelleted supplement. The savings would be slightly lower on mash supplements because no pelleting charges were applied to these rations. In the second scenario, which is similar to the one presently on the Prairies, feeding whole barley would not be economical because the lower savings in milling charges would not offset the loss in broiler performance. Only if the chicken grower could purchase barley at a lower cost than a commercial mill would any savings be realised. Feeding whole wheat and a pelleted supplement would still be economical, with a benefit of 1.0 to 3.4 cents/kg shipped if a maximum of up to 50% whole wheat was fed. The reduced savings in milling charges under this scenario would make it uneconomical to feed more than 50% whole wheat. Few consistent savings could be realised by using whole grain plus a mash supplement compared to feeding just mash unless the chicken grower paid less for the grain than a commercial mill. Chicken growers wanting to add very high levels of wheat or barley on-farm may need to invest in a roller mill or hammer mill to grind the grain; the loss in broiler performance is lower with ground grain than whole grain and the extra investment in equipment may be justified. Whole grain mixing is economical in situations where 1) producers do not want to invest large sums of money in milling equipment, 2) producers have access to cheaper supplies of grain 3) an ntegrated industry exists, and 4) feed mills are running at capacity and do need not to increase margins on supplements compared to complete feed.

TABLE 1. Dietary treatments - % of whole grain in rations (Trials 1 and 2)[1]

Age (d)		Level of whole grain (wheat in Trial 1 and barley in Trial 2)					
Trial 1	Trial 2	1	2	3	4	5	6
0 - 6	0 - 7	0	0	0	5	0	5
6 - 13	7 - 14	0	5	5	20	5	20
13 - 27	14 - 28	0	20	35	35	50	50
27 - 48	28 - 49	0	35	50	50	65	65

[1] Each level of whole wheat feeding was replicated with the remaining ingredients in the diets being fed in pelleted or mash form.

TABLE 2. Dietary composition (%) and nutrient specifications in Trials 1 and 2

	Trial 1			Trial 2		
Ingredients	Starter	Grower	Finisher	Starter	Grower	Finisher
Wheat	55.30	61.98	74.25	39.30	26.00	16.44
Barley	10.00	15.00	10.00	25.00	50.00	65.00
Soybean meal	22.79	14.00	8.50	24.41	12.68	8.00
Meat & bone meal	5.00	5.00	3.50	5.00	7.00	6.92
Limestone	1.05	1.06	1.24	1.02	0.80	0.79
Dical. phosphate	0.89	0.92	1.18	0.88	0.62	0.65
Canola oil	1.00	0.94	0.30	3.29	1.82	1.30
Tallow	2.79	0.00	0.00	0.00	0.00	0.00
Salt	0.25	0.25	0.27	0.26	0.24	0.24
DL Methionine	0.21	0.16	0.08	0.20	0.16	0.06
Lysine HCL	0.20	0.17	0.15	0.14	0.17	0.09
L -Threonine	0.02	0.03	0.03	0.00	0.02	0.00
Vit/min premix[1]	0.17	0.17	0.17	0.17	0.17	0.17
Feed enzyme[2]	0.10	0.10	0.10	0.10	0.10	0.10
Ethoxyquin	0.08	0.08	0.08	0.08	0.08	0.08
Zinc bacitracin[3]	0.05	0.05	0.05	0.05	0.05	0.05
Coxistac[4]	0.10	0.10	0.10	0.10	0.10	0.10
Nutrient specifications						
Crude Protein, %	22.5	19.8	17.4	22.5	19.0	17.0
AME, kcal/kg	3000	2900	2900	2950	2850	2800
MET + CYS, %	0.86	0.72	0.58	0.53	0.72	0.58
Lysine, %	1.25	1.00	0.81	1.25	1.00	0.81

[1] The vitamin mineral mix supplied per kg of complete feed: 11500 IU vitamin A; 2600 IU vitamin D_3; 40 IU vitamin E; 2.5 mg menadione; 2.5 mg thiamine; 10 mg riboflavin; 84 mg niacin; 4 mg pyridoxine; 0.016 mg vitamin B12; 15.4 mg pantothenic acid; 1.1 mg folic acid; 0.14 mg biotin; 0.125 mg antioxidant; 56 mg iron, 77 mg zinc, 95 mg manganese, 7 mg copper, 0.9 mg iodine, 0.21 mg selenium.
[2] Avizyme TX in Trial 1 and Avizyme SX in Trial 2. Both supplied by Finfeeds International Ltd, Marlborough, Wiltshire, 777 UK.
[3] Davis & Lawrence Animal Nutrition, Cambridge, ON, Canada, N3C 2W4.
[4] Pfizer Canada Inc., London, ON, Canada, N6A 4C6.

TABLE 3. Body weight gain (g) of broiler cockerels fed different levels of whole wheat and pelleted/mash supplements (Trial 1)

	Age (d)				
	0 - 6	6 - 13	13 - 27	27 - 48	0 - 48
Level of whole wheat					
1	102	235[a]	904	1641	2882
2	104	238[a]	894	1618	2853
3	104	234[a]	893	1598	2829
4	103	224[bc]	899	1609	2838
5	105	232[ab]	901	1593	2831
6	99	224[c]	894	1587	2804
SEM[1]	2	3	6	19	23
Type of supplement					
Pelleted	108[a]	240[a]	933[a]	1628[a]	2909[a]
Mash	98[b]	223[b]	862[b]	1588[b]	2770[b]
SEM	1	1	3	11	13
Level of whole wheat x type of supplement					
1xPellet	108	244[a]	957[a]	1670	2978
1xMash	97	226[c]	852[c]	1613	2788
2xPellet	107	252[a]	934[ab]	1644	2937
2xMash	101	224[c]	854[c]	1591	2769
3xPellet	111	249[a]	934[ab]	1614	2908
3xMash	97	220[c]	852[c]	1583	2751
4xPellet	106	231[bc]	931[b]	1644	2912
4xMash	100	222[c]	868[c]	1574	2764
5xPellet	110	241[ab]	927[b]	1616	2893
5xMash	101	223[c]	875[c]	1570	2769
6xPellet	103	227[c]	918[b]	1577	2825
6xMash	96	222[c]	869[c]	1596	2783
SEM	3	3	8	27	32

[1] SEM = Standard error of mean.
[a-c] Mean values within a column and main effect with no common superscripts are significantly different ($P<0.05$).

TABLE 4. Feed:gain ratio (mortality corrected) of broiler cockerels fed different levels of whole wheat and pelleted or mash supplements (Trial 1)

	Age (d)				
	0 - 6	6 - 13	13 - 27	27 - 48	0 - 48
Level of whole wheat					
1	1.25	1.32^{c}	1.62^{c}	2.37^{c}	1.99^{d}
2	1.20	1.33^{bc}	1.67^{ab}	2.41^{bc}	2.03^{c}
3	1.21	1.34^{abc}	1.67^{ab}	2.45^{ab}	2.05^{bc}
4	1.22	1.38^{a}	1.65^{b}	2.43^{abc}	2.04^{c}
5	1.20	1.34^{abc}	1.69^{a}	2.48^{a}	2.07^{ab}
6	1.24	1.36^{ab}	1.69^{a}	2.49^{a}	2.08^{a}
SEM[1]	0.02	0.01	0.01	0.02	0.01
Type of supplement					
Pelleted	1.22	1.33^{b}	1.63^{b}	2.45^{b}	2.03^{b}
Mash	1.22	1.36^{a}	1.70^{a}	2.43^{a}	2.06^{a}
SEM	0.01	0.01	0.01	0.01	0.01

[1] SEM = Standard error of mean.
[a-c] Mean values within a column and main effect with no common superscripts are significantly different ($P<0.05$).

TABLE 5. Causes of mortality of broiler cockerels fed different levels of whole wheat and pelleted/mash supplement (Trial 1)

	Level of whole wheat						Supplement	
Causes	1	2	3	4	5	6	Pellet	Mash
SDS[1]	3.99	4.52	4.52	3.46	2.39	1.86	4.08[a]	2.84[b]
Ascites/RHF[2]	1.06	0.53	0.53	0.53	1.33	1.86	1.33	0.62
Skeletal/Leg[3]	3.19[a]	1.06[b]	0.53[b]	1.06[b]	2.39[ab]	1.06[b]	0.98[b]	2.13[a]
Early[4]	0	1.33	0.27	0.53	1.06	1.33	0.62	0.89
Infectious	0	0.53	0	0	0.53	0	0.09	0.27
Other	0.27	0.8	0.80	0.53	0.53	0.53	0.71	0.44
NVL[5]	0.53	0	0.80	0.53	0.80	0	0.71	0.18
Total	9.04	8.78	7.45	6.65	9.04	6.65	8.51	7.36

[1] SDS - Sudden death syndrome.
[2] RHF - Right heart failure.
[3] Skeletal/Leg mortality included valgus varus leg deformity, tibial dyschondroplasia, rotated tibia, spondylolithesis and broken bones.
[a,b] Mean values within a row and main effect with no common superscripts are significantly different ($P<0.05$).

TABLE 6. Dressed and eviscerated carcass yield and organ weight of broiler cockerels fed different levels of whole wheat and pelleted/mash supplements (Trial 1)

	Carcass/organ weight, % of live bird weight								
	Dressed carcass[1]	Evisc. carcass[2]	Offal[3]	Crop	Proven-triclus	Gizzard	Gizzard+ digesta	Small intestine	Abdom. fat pad
Level of whole wheat									
1	78.27	65.71	12.56^{b}	0.26	0.33	1.37^{c}	1.55^{c}	2.06	1.64
2	78.1	65.14	12.94^{ab}	0.26	0.33	1.62^{b}	1.93^{b}	2.03	1.7
3	78.48	65.04	13.44^{a}	0.25	0.34	1.88^{a}	2.18^{a}	2.15	1.8
4	78.66	65.62	13.04^{ab}	0.26	0.35	1.76^{a}	2.05^{ab}	2.06	1.66
5	78.33	64.99	13.34^{a}	0.27	0.34	1.87^{a}	2.17^{a}	2.1	1.76
6	78.87	65.52	13.35^{a}	0.26	0.36	1.83^{a}	2.13^{a}	2.03	1.69
SEM[4]	0.25	0.29	0.17	0.01	0.01	0.04	0.05	0.04	0.08
Type of supplement									
Pelleted	78.44	65.46	12.97	0.26	0.34	1.67^{b}	1.91^{b}	2.01	1.73
Mash	78.47	65.21	13.26	0.26	0.34	1.78^{a}	2.11^{a}	2.1	1.69
SEM	0.15	0.17	0.1	0	0.01	0.02	0.03	0.02	0.05
Whole wheat level x type of supplement interaction	NS	NS	NS	NS	*	*	*	NS	NS

[1] Dressed Carcass = Carcass with feathers, head, neck and feet removed.
[2] Eviscerated Carcass = Dressed carcass with viscera removed.
[3] Offal = Dressed carcass - eviscerated carcass weight.
[4] SEM = Standard error of mean.
[a-c] Mean values within a column and main effect with no common superscripts are significantly different ($P<0.05$).
* $P<0.05$. NS = not significant.

TABLE 7. Particle size distribution of experimental diets (Trial 1)

Age (d)	Diet	Type of supplement	Level of whole wheat (%)	Particle size			
				> 3.3 mm	1.7 - 3.3 mm	1.0 - 3.3 mm	< 1.0 mm
0 - 13	Starter	Crumble	0	13.9	49.6	22.8	13.7
0 - 6	Starter	Crumble	5	12.7	54.3	21.3	11.8
0 - 13	Starter	Mash	0	0.5	23.0	40.6	36.0
0 - 6	Starter	Mash	5	0.6	24.0	37.9	37.5
6 - 13	Starter	Crumble	5	12.7	51.1	22.2	14.1
6 - 13	Starter	Crumble	20	6.8	56.7	22.8	13.8
6 - 13	Starter	Mash	5	0.8	24.2	39.3	35.8
6 - 13	Starter	Mash	20	1.9	36.9	31.6	29.5
13 - 27	Grower	Crumble	0	41.8	44.7	8.2	5.3
13 - 27	Grower	Crumble	20	34.5	54.0	7.5	4.0
13 - 27	Grower	Crumble	35	31.8	56.0	6.5	5.8
13 - 27	Grower	Crumble	50	25.8	64.7	5.6	3.9
13 - 27	Grower	Mash	0	0.3	20.8	38.0	40.9
13 - 27	Grower	Mash	20	2.0	31.7	30.6	35.7
13 - 27	Grower	Mash	35	3.1	42.6	25.0	29.4
13 - 27	Grower	Mash	50	4.5	53.9	18.9	22.8
27 - 48	Finisher	Pellet	0	90.6	4.3	3.1	2.1
27 - 48	Finisher	Pellet	35	54.2	36.2	3.8	5.8
27 - 48	Finisher	Pellet	50	49.5	46.4	1.9	2.2
27 - 48	Finisher	Pellet	65	33.8	61.8	2.1	2.2
27 - 48	Finisher	Mash	0	0.3	26.8	38.6	34.3
27 - 48	Finisher	Mash	35	4.2	45.1	25.2	25.6
27 - 48	Finisher	Mash	50	5.2	55.4	17.9	21.6
27 - 48	Finisher	Mash	65	6.1	63.9	12.6	17.5

TABLE 8. Body weight gain (g) of broiler cockerels fed different levels of whole barley and pelleted/mash supplements (Trial 2)

	Age (d)				
	0 - 7	7 - 14	14 - 28	28 - 49	0 - 49
Level of whole barley					
1	79[a]	207	831	1670[a]	2787[a]
2	72[c]	204	817	1593[b]	2686[b]
3	71[c]	204	825	1618[b]	2718[b]
4	78[ab]	204	828	1591[b]	2702[b]
5	73[bc]	203	823	1607[b]	2706[b]
6	78[ab]	205	836	1610[b]	2729[ab]
SEM[1]	2	2	6	16	21
Type of supplement					
Pelleted	79[a]	211[a]	852[a]	1634[a]	2776[a]
Mash	71[b]	198[b]	802[b]	1596[b]	2667[b]
SEM	1	1	6	9	12
Level of whole barley x type of supplement					
1xPellet	85[a]	212	866[a]	1709	2872
1xMash	72[b]	202	796	1632	2702
2xPellet	74[b]	211	848[ab]	1611	2744
2xMash	69[b]	198	787	1575	2682
3xPellet	71[b]	206	840[abc]	1646	2764
3xMash	71[b]	202	810[de]	1590	2672
4xPellet	86[a]	215	861[a]	1621	2783
4xMash	71[b]	194	795	1562	2622
5xPellet	74[b]	208	830[bcd]	1607	2720
5xMash	73[b]	198	816[cde]	1607	2693
6xPellet	85[a]	216	864a[a]	1606	2771
6xMash	72[b]	195	807[de]	1614	2688
SEM					

[1] SEM = Standard error of mean.
[a-e] Mean values within a column and main effect with no common superscripts are significantly different ($P<0.05$).

TABLE 9. Feed:gain ratio (mortality corrected) of broiler cockerels fed different levels of whole barley and pelleted/mash supplements (Trial 2)

	Age (d)				
	0 - 7	7 - 14	14 - 28	28 - 49	0 - 49
Level of whole barley					
1	1.283^{c}	1.249	1.635^{c}	2.327^{c}	2.004^{b}
2	1.457^{a}	1.281	1.661^{ab}	2.360^{bc}	2.037^{a}
3	1.398^{ab}	1.28	1.651^{bc}	2.384^{ab}	2.044^{a}
4	1.277^{c}	1.289	1.665^{ab}	2.408^{a}	2.056^{a}
5	1.394^{ab}	1.285	1.674^{a}	2.385^{ab}	2.053^{a}
6	1.329^{bc}	1.293	1.675^{a}	2.387^{ab}	2.050^{a}
SEM[1]	0.033	0.008	0.004	0.015	0.01
Type of supplement					
Pelleted	1.349	1.284	1.661	2.385	2.042
Mash	1.364	1.275	1.659	2.365	2.039
SEM	0.019	0.013	0.007	0.009	0.005
Level of whole barley x type of supplement					
1xPellet	1.25	1.259	1.618	2.325^{d}	1.994^{d}
1xMash	1.317	1.239	1.651	2.328^{cd}	2.015^{cd}
2xPellet	1.485	1.257	1.662	2.365^{bcd}	2.032^{bcd}
2xMash	1.43	1.306	1.66	2.356^{bcd}	2.041^{abc}
3xPellet	1.416	1.292	1.648	2.385^{abcd}	2.045^{abc}
3xMash	1.379	1.268	1.654	2.383^{abcd}	2.044^{abc}
4xPellet	1.238	1.311	1.669	2.399^{abc}	2.046^{abc}
4xMash	1.316	1.268	1.66	2.418^{ab}	2.066^{ab}
5xPellet	1.411	1.274	1.682	2.394^{abcd}	2.056^{abc}
5xMash	1.377	1.295	1.667	2.376^{abcd}	2.050^{abc}
6xPellet	1.294	1.31	1.687	2.445^{a}	2.080^{a}
6xMash	1.364	1.276	1.663	2.329^{cd}	2.021^{cd}
SEM					

[1] SEM = Standard error of mean.

[a-d] Mean values within a column and main effect with no common superscripts are significantly different ($P<0.05$).

TABLE 10. Causes of mortality of broiler cockerels fed different levels of whole barley and pelleted/mash supplement (Trial 2)

	Level of whole barley						Supplement	
Causes	1	2	3	4	5	6	Pellet	Mash
SDS[1]	3.5	2.2	4.6	3.5	3.3	2.2	3.5	2.9
Ascites/RHF[2]	0	1.6	1.1	0.5	0.5	1.4	1.4[a]	0.4[b]
Skeletal/Leg[3]	0.5	0.3	0.8	0.3	0.8	0.3	0.3	0.7
Early[4]	0.5	0	0	0.5	0	0.3	0.1	0.4
Infectious	0	0	0	0	0	0.3	0	0.1
Other	0.5	0	0.5	0.5	0	0.3	0.4	0.3
NVL[5]	0.8	0.5	0.5	0.5	0	0.5	0.5	0.5
Total	6.0	4.6	7.6	6.0	4.6	5.2	6.1	5.3

[1] SDS - Sudden death syndrome.
[2] RHF - Right heart failure.
[3] Skeletal/Leg mortality included valgus varus leg deformity, tibial dyschondroplasia, rotated tibia, spondylolithesis and broken bones.
[a,b] Mean values within a row and main effect with no common superscripts are significantly different ($P<0.05$).

TABLE 11. Particle size distribution of experimental diets (Trial 2)

Age (d)	Diet	Type of supplement	Level of whole barley (%)	Particle size			
				> 3.3 mm	1.7 - 3.3 mm	1.0 - 3.3 mm	< 1.0 mm
0 – 14	Starter	Crumble	0	10.0	54.3	20.1	15.6
0 – 7	Starter	Crumble	5	14.3	61	16.4	8.4
0 – 14	Starter	Mash	0	0.7	20.9	36.4	42.1
0 – 7	Starter	Mash	5	4.7	20.5	34.1	40.8
7 – 14	Starter	Crumble	5	10.8	48.3	23.2	17.6
7 – 14	Starter	Crumble	20	18.1	37.7	23.0	21.2
7 – 14	Starter	Mash	5	4.9	20.0	34.7	40.4
7 – 14	Starter	Mash	20	17.2	18.3	29.6	34.9
14 – 28	Grower	Crumble	0	26.9	44.0	14.8	14.3
14 – 28	Grower	Crumble	20	33.4	40.0	14.9	11.7
14 – 28	Grower	Crumble	35	44.1	35.8	11.6	8.5
14 – 28	Grower	Crumble	50	50.9	28.7	11.3	9.0
14 – 28	Grower	Mash	0	1.8	23.0	34.8	40.3
14 – 28	Grower	Mash	20	16.7	18.6	28.4	36.1
14 – 28	Grower	Mash	35	27.8	18.3	25.0	29.0
14 – 28	Grower	Mash	50	40.3	16.1	20.4	23.2
28 – 49	Finisher	Pellet	0	65.5	8.6	9.9	17.0
28 – 49	Finisher	Pellet	35	66.1	10.5	10.4	12.9
28 – 49	Finisher	Pellet	50	75.5	7.5	7.3	9.7
28 – 49	Finisher	Pellet	65	70.3	12	6.8	10.9
28 – 49	Finisher	Mash	0	2.0	25.7	33.8	38.5
28 – 49	Finisher	Mash	35	28.9	21.1	23.0	27.0
28 – 49	Finisher	Mash	50	40.3	16.5	18.4	24.7
28 – 49	Finisher	Mash	65	56.1	14.3	12.1	17.5

TABLE 12. Effect of diet on cost of chicks + feed ingredients + pelleting + trucking + other milling charges, $/ kg shipped (Trial 1)

Type of Supplement	Level of whole wheat						Average
	1	2	3	4	5	6	
Scenario 1: Assume milling charges same per tonne of complete feed and supplement							
Pelleted	0.748	0.733	0.716	0.692	0.732	0.714	0.722
Mash	0.736	0.718	0.721	0.731	0.718	0.696	0.720
Average	0.742	0.725	0.719	0.711	0.725	0.705	
Scenario 2: Assume milling charges per tonne of supplement higher than per tonne of complete feed							
Pelleted	0.748	0.747	0.738	0.714	0.762	0.748	0.742
Mash	0.736	0.733	0.744	0.754	0.748	0.726	0.74
Average	0.742	0.740	0.741	0.734	0.755	0.736	

TABLE 13. Effect of diet on cost of chicks + feed ingredients + pelleting + trucking + other milling charges, $/ kg shipped (Trial 1)

Type of Supplement	Level of whole barley						Average
	1	2	3	4	5	6	
Scenario 1: Assume milling charges same per tonne of complete feed and supplement							
Pelleted	0.699	0.692	0.685	0.672	0.664	0.67	0.68
Mash	0.693	0.682	0.681	0.683	0.656	0.656	0.675
Average	0.696	0.687	0.683	0.677	0.66	0.663	
Scenario 2: Assume milling charges per tonne of supplement higher than per tonne of complete feed							
Pelleted	0.699	0.707	0.707	0.694	0.693	0.700	0.700
Mash	0.693	0.697	0.703	0.706	0.685	0.685	0.695
Average	0.696	0.702	0.705	0.700	0.689	0.693	

TABLE 14. Effect of feeding program on whole wheat consumed as a percentage of total feed intake and total milling costs[1] (Trial 1)

Type of Supplement	Level of whole wheat						Average
	1	2	3	4	5	6	
Whole wheat consumption, % of total intake							
Pelleted	0	28.6	42.3	43.5	56.2	57.2	38.0
Mash	0	28.7	42.6	43.4	56.4	57.5	38.1
Average	0	28.6	24.5	43.4	56.3	57.3	
Total milling and trucking cost, $/kg shipped							
Scenario 1: Assume milling charges same per tonne of complete feed and supplement							
Pelleted	0.093	0.067	0.055	0.052	0.430	0.410	0.058
Mash	0.081	0.059	0.048	0.048	0.037	0.036	0.052
Average	0.087	0.063	0.051	0.050	0.040	0.038	
Scenario 2: Assume milling charges per tonne of supplement higher than per tonne of complete feed							
Pelleted	0.093	0.082	0.077	0.074	0.073	0.710	0.078
Mash	0.081	0.074	0.071	0.710	0.068	0.066	0.072
Average	0.087	0.078	0.074	0.073	0.071	0.068	

[1] Total milling = pelleting + trucking + other milling charges

TABLE 15. Effect of feeding program on whole barley consumed as a percentage of total feed intake and total milling costs[1] (Trial 2)

Type of Supplement	Level of whole barley						Average
	1	2	3	4	5	6	
Whole barley consumption, % of total intake							
Pelleted	0	29.0	43.1	43.8	57.0	57.8	38.4
Mash	0	29.2	43.2	44.1	57.2	58.0	38.6
Average	0	29.1	43.1	43.9	57.1	57.9	
Total milling and trucking cost, $/kg shipped							
Scenario 1: Assume milling charges same per tonne of complete feed and supplement							
Pelleted	0.091	0.066	0.053	0.052	0.04	0.04	0.057
Mash	0.08	0.058	0.047	0.046	0.035	0.034	0.05
Average	0.085	0.062	0.050	0.049	0.037	0.037	
Scenario 2: Assume milling charges per tonne of supplement higher than per tonne of complete feed							
Pelleted	0.091	0.081	0.076	0.074	0.069	0.07	0.077
Mash	0.080	0.073	0.069	0.069	0.064	0.064	0.070
Average	0.085	0.077	0.073	0.072	0.067	0.067	

[1] Total milling = pelleting + trucking + other milling charges

EXPERIMENT 5

FEEDING WHOLE WHEAT WITH OR WITHOUT A DIETARY ENZYME OR GRIT AND/OR PHYSICAL FORM OF DIET TO LAYING HENS

H. Kermanshahi, H.L. Classen and C.D. Bennett

ABSTRACT

Two experiments were conducted to determine the impact of feeding whole wheat on the performance of laying hens. Experiment was designed as a 3x2x2 factorial with three levels of whole wheat (0, 10 or 20%), the use of a microbial enzyme source (0 or 0.1%) and two levels of number 3 size white granite grit (0 or 1%). The second experiment was a 2x2 factorial design with two levels of whole wheat (0 or 50%) and two diet forms (mash or pellet). Addition of whole wheat was at the expense of wheat in the diet so no diet dilution occurred. Feeding either 20 or 50% to laying hens did not affect flock performance or egg quality. Other dietary treatments had only minor effects on the performance of laying hens. Whole wheat can be fed to laying hens at levels up to 50% of the diet.

INTRODUCTION

Wheat is an important cereal component in poultry rations in many parts of the world. Today, most commercial wheat based diets are fed to poultry in either a pelleted or crumbled form. However, there is some evidence indicating that laying hens are able to maintain their feed intake for satisfactory production regardless of cereal particle size (Ouart *et al.* 1986). Some early (McIntosh *et al.* 1964; O'Neil 1964) and recent studies (Rose *et al.* 1995) have also indicated that whole wheat can be fed to growing and laying birds with little or no adverse effect on performance. The cost of feed processing (grinding, mixing, pelleting, handling, transportation) can increase the price of cereal grains used in poultry diets. Rose *et al.* (1995) found processing increased grain costs by over a fifth in most compounding operations while Koci and Kociova (1994) showed that using whole wheat decreased feed costs by 7.4 to 17.6%. Robinson (1985) also showed more overall return from using whole than ground wheat in laying hen diets. He indicated that a diet based on whole wheat would be ideal for feeding laying hens in a free choice situation.

Several studies have reported that the inclusion of degradative enzymes in animal feed can increase the availability of nutrients (Van der Klis, 1995; Hew *et al.* 1995). Addition of non starch polysaccharide (NSP) degrading enzymes decreases the anti-nutritive activity of NSP present in wheat (Choct and Annison 1990; Bedford and Classen 1992; Annison 1992).

It is generally conceded that feeding insoluble grit is not beneficial for hens fed a mash diet (Walters and Aitken 1961; Proudfoot 1973; Proudfoot and Hulan 1987). The value of insoluble grit in diets containing whole grain remains in question. The bird's gizzard is capable of grinding whole grains and some research supports the use of insoluble grit to aid this process (Zuhair and Elwinger 1988).

The primary objective of this research was to investigate the potential of feeding whole wheat to laying hens. The use of NSP degrading enzymes and insoluble grit in whole grain feeding programs was examined as well as the combination of whole grain with mash and pelleted supplements.

MATERIALS AND METHODS

Two experiments were completed to meet the objectives of the research. In Trial 1, the effect of feed enzymes and insoluble grit on laying hen performance when feeding whole grain was investigated. The trial was designed as a 3x2x2 factorial arrangement with the dietary main effects of level of whole wheat (0, 10 or 20%), use of a microbial enzyme source (0 or 0.1%; Avizyme TX[1]) and the inclusion of insoluble grit (0 or 1%; number 3 layer size, white granite). The enzyme source contained multiple activities but was established to contain a high level of endo-xylanase. Each dietary treatment was replicated four times with ten hens per replication. The experimental period was from 19 to 54 weeks of age.

In Trial 2, feeding of high levels of whole wheat in combination with mash or pelleted supplements was studied. A 2x2 factorial design was used to determine effect of level of dietary whole wheat (0 or 50%) and form of the non-whole grain portion of the diet (mash or pellet). Pellets were formed using a 4.76mm die size. No insoluble grit was fed. Each dietary treatment was replicated 12 times using ten hens per replication. Data collection occurred from 19-43 weeks of age.

In both trials, day-old Single Comb White leghorn pullets were placed in litter floor pens and reared using standard procedures for temperature and ventilation control. Pullets were beak trimmed at 10 days of age. The birds were fed starter, grower and prelay diets from 0 to 6, 6 to 17 and 17 to 19 weeks of age, respectively. The prelay diet contained 2750 kcal/kg ME and 16% CP. Except for the prelay rations in Trial 2, all starter, grower and prelay diets were fed in mash form and without insoluble grit. In Trial 2, the birds destined to be fed a whole wheat layer ration, were fed a prelay diet containing 10% whole grain while those that would not be fed whole grain received an all mash prelay ration.

The pullets were randomly housed 2 birds per cage (30.5 x 45.7 cm) at 18 weeks of age. The photoperiod length was maintained at 8L:16D until the initiation of the experiments at 19 weeks of age when it was increased to 14L:10D. Light intensity was maintained at 5 lux during the experiments. Experimental diets are shown in Tables 1 and 2. Feeds and water were available as an *ad libitum* basis.

Egg production was recorded 5 days per week for the length of the experiments and converted mathematically to 7 day period production prior to statistical analysis. Egg weight and specific gravity measurements were made on all eggs produced during 1 day per 28 day period. Eggs were weighed the same day as collected, then stored in common room over night (6° C). Specific gravity was determined the following morning using salt solutions ranging from 1.060 to 1.100 with gradations of 0.005. Mortality was

[1] Finfeeds International Ltd, Marlborough, Wiltshire, 777 UK.

recorded daily. Feed consumption was determined every 4 weeks and all hens were weighed at 19 weeks of age as well as at the end of each trial.

Data were analyzed as a 3x2x2 and 2x2 factorial arrangements in Experiments 1 and 2, respectively. SAS® program (1985) was used for the analysis of variance and when significant, the Duncan's multiple range test was used to separate means. Differences between treatment means were considered statistically significant at $P<0.05$.

RESULTS

Trial 1

The use of whole wheat up to a level of 20%, a microbial enzyme source or insoluble grit in the diet had no effect on egg production on a hen-day, hen-housed or egg mass basis (Table 3). Feed intake and efficiency were not affected by feeding whole wheat or insoluble grit. The use of the dietary enzyme reduced feed intake. While not statistically significant, the use of enzyme numerically improved feed to egg mass ratio and feed per dozen eggs by 1.1 and 3.0% respectively. Hen mortality and body weight gain, as well as egg weight, were unaffected by dietary treatment. Enzyme addition increased egg specific gravity but whole wheat and grit did not. There were no interactions among main effects.

Trial 2

Feeding 50% whole wheat in combination with either mash or pelleted supplements had no effect on egg production, feed efficiency, mortality, weight gain, egg weight or specific gravity (Table 4). There were no interactions between level of whole wheat and the physical form of the diet. Feeding a pelleted diet caused a minor increase in the incidence of misshapen eggs (Mash – 0.03%; Pellet – 0.08%).

DISCUSSION AND CONCLUSIONS

These results are in agreement with previous research showing that poultry can effectively digest whole wheat. Grit is not necessary for birds to efficiently utilize whole grain. In Trial 1, no improvement in performance was observed when adding grit and in Trial 2, birds fed 50% whole grain performed well without any grit being supplied. Feed enzymes can be beneficial for birds fed wheat based diets, causing an decrease in feed intake and increase in egg shell quality, but the effect is the same whether the wheat included in the diet is in whole grain or mash form. High levels of whole wheat can be mixed with either mash or pelleted supplements with no negative effect on performance. Feeding whole wheat can reduce feed processing and handling costs without lowering bird performance on farm.

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TABLE 1. Composition (%) of diets with 0, 10 and 20% whole wheat (Trial 1)[1]

Ingredients[2]	0	10	20
Whole wheat	0	10	20
Ground wheat	70.6	60.6	50.6
Avizyme TX[3]	0	0	0
Grit	0	0	0
Constant[4]	29.4	29.4	29.4

[1] In diets with enzyme and/or grit, the enzyme or grit, all of the ingredients above were reduce proportionately to allow inclusion of these extra ingredients.

[2] On a calculated basis, diets contained (%): ME, 2800 kcal/kg; CP, 17.7; calcium, 3.8; available phosphorous, 0.42; sodium, 0.18; methionine, 0.42; methionine and cysteine, 0.69; lysine, 0.87.

[3]Finnfeeds International Ltd., Marlborough, 777 U.K.; 300,000 U endoxylanase/g.

[4]Constant ingredients were (%): soybean meal 16.01; canola oil 1.85; limestone 8.85, dicalcium phosphate 0.18; salt, 0.34; DL- methionine 0.17; vitamin and mineral premixes, 2.0. The latter provided the following per kg of ration: vitamin A, 10000 IU; vitamin D, 2500 IU; vitamin E, 25 IU; vitamin K, 1.5 mg; thiamine, 1 mg; riboflavin, 7.5 mg; niacin, 30 mg; vitamin B_6, 4 mg; vitamin B_{12}, .015 mg; pantothenic acid, 8 mg; folic acid, .5 mg; biotin, .1 mg; choline, 400 mg; iron, 80 mg; vitamin C, 25 mg; zinc, 80 mg; manganese, 80 mg; copper, 10 mg; iodine, .8 mg; cobalt, .25 mg; selenium, .3 mg; calcium, 3200 mg; and phosphorous, 2000 mg.

[1] On a calculated basis, diets contained (%): ME, 2677 kcal/kg; CP, 18.0 ; calcium, 4.0; available phosphorous, 0.45; sodium, 0.18; methionine, 0.44;; methionine and cysteine, 0.72; and. lysine, 0.94.

[2] Constant ingredients were (%): soybean meal 18.75; canola oil 1.0; limestone 4.30; large particle limestone, 5.0; dicalcium phosphate 0.32; salt, 0.35; DL-methionine, 0.17; and vitamin and mineral premixes, 2. The latter provided the following per Kg of ration: vitamin A, 10000 IU; vitamin D, 2500 IU; vitamin E, 25 IU; vitamin K, 1.5 mg; thiamine, 1 mg; riboflavin, 7.5 mg; niacin, 30 mg; vitamin B6, 4 mg; vitamin B12, .015 mg; pantothenic acid, 8 mg; folic acid, .5 mg; biotin, .1 mg; choline, 400 mg; iron, 80 mg; vitamin C, 25 mg; zinc, 80 mg; manganese, 80 mg; copper, 10 mg; iodine, .8 mg; cobalt, .25 mg; selenium, .3 mg; calcium, 3200 mg; phosphorous, 2000 mg; and Avizyme 1100, 0.1% (Finnfeeds International Ltd., Marlborough, 777 U.K.).

EXPERIMENT 6

HIGH WHEAT DIETS FOR BROILERS – AMINO ACID REQUIREMENTS DURING THE GROWER AND FINISHER PHASES

C.D. Bennett and H.L. Classen

ABSTRACT

1. Some types of whole wheat feeding programs utilise diet dilution as a way of reducing costs and improving the net returns of broiler production. Since diet dilution can potentially reduce nutrient (amino acids) intake to a point that performance is affected, it is important to know the requirements of broilers during the period of time when whole wheat feeding is at its highest level (grower and finisher diets). This research was designed to provide that information for a high wheat diet. More specifically, the trial investigated the effect of feeding diets containing very high levels of wheat in the grower and finisher phases with different levels of amino acids and crude protein when the soybean meal and meat meal were replaced with increasing amounts of wheat. The study also investigated the use of synthetic lysine, methionine and threonine to improve bird performance on high wheat, low soybean meal and meat meal diets. Male and female broilers responded similarly to reductions in crude protein in the grower and finisher, reducing growth rate and increasing feed:gain as the soybean and meat meal in the diet was replaced with wheat. Unexpectedly, adding extra synthetic amino acids reduced growth rate and increased feed:gain at the lower levels of crude protein. The most economical level of soybean plus meat meal in the diet was 19% in the grower and 17% in the finisher. The birds fed these rations had cumulative body weight gain, feed:gain, breast meat yield and total meat yield the same as the birds fed the highest level of crude protein. These levels are slightly lower than used in industrial feeding and may account for the successful dilution of broiler diets using whole wheat.

MATERIAL AND METHODS

Wheat, barley, soybean meal and meat meal were the major feed ingredients and all diets were formulated to contain 3000 kcal/ME per kg of diet. The control diets were formulated to feed specifications similar to those used in a 1993 broiler trial at the University of Saskatchewan (CTR9326) which produced rapid growth rates. The experimental diets were formulated to 92.5%, 85.0% or 77.7% of the crude protein, lysine, methionine + cysteine and threonine found in the control diets (Trt 1). The ratio of soybean meal to meat meal was be kept constant at 4:1 in all diets. In some of the treatments, the crude protein was reduced but the lysine, methionine + cysteine and threonine were maintained at control levels by using synthetic amino acids. The level of crude protein and amino acids of the rations used in the 12 dietary treatments are displayed in Table 1.

All birds were fed the same starter diet until 14 days of age. The grower diets were fed from 14 to 28 days and the finisher diets from 28 to 41 days. The ingredient composition of the starter, grower and finisher rations is shown in Table 2.

A total of 1,200 sexed Hubbard x Hubbard chicks were housed in 8 environmentally controlled rooms, with half of the rooms containing cockerels and the other half pullets. Within each room, 50 chicks were placed in each of 12 pens and 1 of the 12 dietary treatments was randomly assigned to each pen. At 14 days of age, birds dying in the first 2 weeks were replaced with spare chicks raised on the experimental starter diet.

All birds were reared under an increasing lighting program. Normal temperature and ventilation rates for brooding broiler chickens were maintained.

All birds were group weighed by pen at 0, 14, 28, and 41 days of age and feed intake was determined at the same ages. Feed:gain ratio was corrected for mortality by including the weight of the mortality in the weight gain.

Twenty pullets and 20 cockerels from each treatment were selected for meat yield determination at 41 days of age, giving a total of 480 birds for the whole trial. These birds were randomly chosen, 5 per pen, individually weighed and double wing banded. After processing, eviscerated carcass weight, breast and fillet weight, meat weight from one thigh and one drum as well as bone-in weight for one thigh and drum were measured.

Using SAS (1994), the data was analysed as a 2 (sex) x 12 (diet) factorial design with sex nested within room. When appropriate, means were separated using Duncan's multiple range test. Statistical significance was accepted at the 5% confidence level ($P<0.05$).

RESULTS

Body weight gain data for the trial are displayed in Table 3. From 14 to 28 days of age, almost all of the birds fed 92.5% of the control level of crude protein (Trts 2, 7, 9, 10, 11, 12) had similar body weight gain to the bird fed the control rations (Trt 1), the only exception being the slightly lower gain of the birds in Trt 8. The birds fed 85% of the control crude protein level (Trts 3,6) had lower body weight gain than birds in most of the treatments fed 92.5% or 100% of the control levels. The birds fed 77.5% of control levels of crude protein (Trts 4, 5) gained less than birds in all other treatments.

A slightly different trend was noted from 28 to 41 days of age. Feeding 85%, 92.5% or 100% of control levels of crude protein produced similar body weight gain as long as extra synthetic amino acids were not used to bring amino acid levels up to that of the controls (Trts 1, 2, 3, 7, 9). Birds fed 85% or 92.5% of the crude protein level plus extra synthetic amino acids (Trts 6, 8, 10, 12) had body gain greater than most birds 77.5% of control crude protein levels (Trts 4, 5, 11, 12), the only exceptions being Trt. 6 vs Trt 4 and Trts 6, 8, 10 vs Trt 11. Adding extra synthetic amino acids at 77.5%, 85%, and 92.5% of control crude protein level never improved body weight gain and in three instances decreased it (Trts 3 vs 6, 4 vs 5, 11 vs 5).

Total weight gain from 14 to 41 days was similar for birds fed 85%, 92.5% or 100% of control crude protein levels as long as extra synthetic amino acids were not used in the finisher (Trts 1, 2, 3, 7, 9). Birds fed 85% or 92.5% of control crude protein plus extra synthetic amino acids (Trts 6, 8, 10) had higher body weight gain than the some of the birds fed 77.5% of control crude protein with or without extra amino acids (Trts 4, 5, 11, 12), the exceptions being Trts 6 vs 4, Trts 6, 8, 10 vs 11 and Trts 6, 8 vs 12. Because

some birds were fed extra synthetic amino acids in the grower but not the finisher or vice versa, the effect of extra supplementation on total weight gain was more difficult to determine over the total trial. Three comparisons could be made in which birds were fed the same level of crude protein in the grower and finisher, with and without extra amino acids, and in two cases extra supplementation decreased body weight gain (Trt 2 vs 8, 4 vs 5).

Feed efficiency was improved by feeding higher levels of crude protein but was not as greatly influenced by extra synthetic amino acid supplementation (Table 4). From 14 to 28 days of age, almost all of the birds fed 92.5% or 100% of control crude protein level had similar feed:gain (Trts 1, 2, 7, 8, 9,10, 11, 12), the exception being the birds in Trt 7 having a lower feed:gain than all but those in Trt 1. Birds fed 85% of control crude protein, with or without extra synthetic amino acids(Trts 3, 6), converted feed less efficiently than those fed higher levels of crude protein but more efficiently than those fed the lowest level. At the 77.5% crude protein, feeding extra synthetic amino acids in the grower did increase feed:gain (Trt 5 vs 4).

From 28 to 41 days of age, birds fed 92.5% or 100% of control crude protein had similar feed conversions regardless of level of amino acid supplementation (Trts 1, 2, 7, 8). Most of the birds in treatments fed 85% of the control crude protein level, with or without extra amino acids, had similar feed:gain (Trts 3, 6, 9, 10), the only exception being Trt 3 vs 6. Feeding 77.5% of control crude protein level increased feed:gain compared to feeding higher levels of crude protein, the exception being Trt 4 vs 6, 9, 10. Extra amino acid supplementation did increase feed:gain at the lowest level of crude protein (Trts 4 vs 5, 4 vs 12, 11 vs 12).

Total feed:gain was similar for birds fed 92.5% or 100% of control crude protein for the entire trial regardless of amino acid supplementation (Trts 1, 2, 7, 8). Birds fed 85% of crude protein in the grower and/or finisher tended to have a feed:gain intermediate to those fed higher or lower levels of crude protein with no significant effect of extra amino acid supplementation. Birds fed 77.5% of crude protein levels for all or part of the trial had a higher feed:gain than birds in almost all other treatments, the exceptions being Trt 12 vs 6 and Trt 11 vs 3, 6. When the lowest level of crude protein was fed in both the grower and finisher, total feed:gain was increased (Trt 5 vs 4).

Dietary treatment had a limited effect on carcass yield or composition (Table 5). No significant treatment effects were observed for yield of breast meat, thigh, thigh meat, drumstick, wings, rack, total bone or total skin. Drumstick meat yield was comparable for most treatments but, compared to some treatments, was lower in birds fed low levels of crude protein in both the grower and finisher (Trts 4, 5) and the birds in Trt 8. Total meat yield was only reduced by feeding the lowest level of crude protein for the life of the trial (Trts 4, 5). Abdominal fat pad was similar for many birds (Trts 1, 2, 5, 6, 8 , 9, 10, 11) but tended to be higher in same instances where 77.5% or 85% of control crude protein levels were fed.

The cockerels had larger weight gain and lower feed:gain than the pullets but the two sexes responded similarly to the different dietary treatments. The males had less pectoralis minor (breast fillet), skin and rack but more drumstick (bone-in)and drumstick meat than the females.

In Table 6, the cost of feed and chick per kg shipped was calculated for each treatment. Costs from October, 1995 were and it was assumed that the feed was made as a complete ration by a commercial mill that charged milling fee of $40/tonne. For male broilers, the lowest feed and chick cost occurred in Trts 1 and 7 in which the birds were fed the maximum or next to maximum crude protein level in both the grower and finisher; feeding 85% or less of control crude protein level at any time numerically increased the cost of the rearing the birds. For pullets, the lowest costs occurred with Trts 2, 7 and 9 in which 92.5% of control crude protein levels were fed in the grower and 85% to 92.5% in the finisher. For a mixed flock with half males and females, the feed and chick cost was lowest in Trts 2 and 7 where 92.5% of control crude protein levels were fed, although the average cost for several other treatments was within 1.5 cents/kg shipped. In the two treatments with the lowest live bird production cost, the combined level of soybean plus meat meal averaged 19% in the grower and 17% in the finisher. The cereal grain (wheat + barley) in these same rations averaged 69% in the grower and 77% in the finisher.

TABLE 1. Protein and amino acid levels

	Treatment											
	1	2	3	4	5	6	7	8	9	10	11	12
Grower Diet												
As a % of Controls												
Protein	100	92.5	85	77.5	77.5	85	92.5	92.5	92.5	92.5	92.5	92.5
AA	100	92.5	85	77.5	100	100	100	100	100	100	100	100
As % of Diet												
Protein	21.000	19.425	17.850	16.275	16.275	17.850	19.425	19.425	19.425	19.425	19.425	19.425
MET & CYS	0.770	0.712	0.655	0.597	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.770
Lysine	1.060	0.981	0.901	0.822	1.060	1.060	1.060	1.060	1.060	1.060	1.060	1.060
Threonine	0.750	0.694	0.638	0.581	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Finisher Diet												
As % of Controls												
Protein	100	92.5	85	77.5	77.5	85	92.5	92.5	85	85	77.5	77.5
AA	100	92.5	85	77.5	100	100	92.5	100	85	100	77.5	100
As % of Diet												
Protein	20.000	18.500	17.000	15.500	15.500	17.000	18.500	18.500	17.000	17.000	15.500	15.500
MET & CYS	0.675	0.624	0.574	0.523	0.675	0.675	0.624	0.675	0.574	0.675	0.523	0.675
Lysine	0.950	0.879	0.808	0.736	0.950	0.950	0.879	0.950	0.808	0.950	0.736	0.950
Threonine	0.705	0.652	0.599	0.546	0.705	0.705	0.652	0.705	0.599	0.705	0.546	0.705

All diets are formulated to 3000 kcal/kg.

TABLE 2. Ingredient composition of diets

	Starter, 0 to 14 d	Grower, 14 to 28 d							Finisher, 28 to 41 d						
		Treatment													
Treatment	1 - 12	1	2	3	4	5	6	7- 11	1	2,7	3,9	4,11	5,12	6,10	8
Ingredient, % of diet															
Wheat	530.0	542.0	589.9	637.7	685.5	693.1	642.8	592.4	570.8	616.6	662.2	707.9	714.8	666.8	618.8
Soybean meal	236.2	190.8	153.2	115.6	78.1	66.1	107.6	149.2	169.5	133.4	97.5	61.5	50.7	90.3	129.9
Meat meal	60.0	47.7	38.3	28.9	19.5	16.5	26.9	37.3	42.4	33.4	24.4	15.4	12.7	22.6	32.5
Limestone	8.6	10.6	11.7	12.8	13.8	14.2	13.0	11.8	11.2	12.3	13.3	14.3	14.6	13.5	12.4
Dical. P	5.6	9.5	11.2	12.8	14.5	15.0	13.2	11.3	10.4	12.0	13.6	15.2	15.7	13.9	12.2
Barley	100.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
Tallow	47.8	39.2	34.9	30.6	26.2	25.2	29.9	34.5	36.7	32.5	28.4	24.3	23.3	27.8	32.2
DL Methionine	1.99	1.63	1.51	1.40	1.28	3.24	2.70	2.16	0.92	0.86	0.80	0.74	2.45	1.94	1.43
Salt	2.45	2.55	2.68	2.82	2.95	3.00	2.85	2.70	2.63	2.75	2.88	3.00	3.05	2.91	2.77
Lysine HCL	1.92	0.91	1.45	1.99	2.53	6.13	4.39	2.65	0.37	0.96	1.54	2.12	5.35	3.69	2.03
Stafac 22	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Coxistac	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Threonine	0.00	0.11	0.27	0.43	0.58	2.55	1.74	0.92	0.06	0.25	0.38	0.57	2.39	1.61	0.83

TABLE 3. Average body weight gain and 41 day body weight (kg)

	Treatment												
	1	2	3	4	5	6	7	8	9	10	11	12	Sex Ave.
Body weight gain (kg/bird)													
14 to 28 days of age													
Males	.984	.973	.942	.928	.916	.949	1.001	.944	.977	.974	.970	.979	.961[A]
Females	.814	.828	.801	.777	.771	.809	.820	.815	.814	.826	.817	.827	.821[B]
Average	.899[a]	.900[a]	.871[c]	.852[d]	.844[d]	.879[bc]	.910[a]	.879[bc]	.895[ab]	.900[a]	.894[ab]	.903[a]	
28 to 41 days of age													
Males	1.203	1.203	1.164	1.062	1.021	1.106	1.191	1.131	1.152	1.133	1.124	1.066	1.130[A]
Females	.973	.963	.968	.926	.871	.923	.976	.958	.951	.932	.917	.892	.937[B]
Average	1.088[a]	1.083[ab]	1.066[abc]	.994[ef]	.946[g]	1.014[def]	1.084[ab]	1.044[bcd]	1.052[abcd]	1.033[cd]	1.020[de]	.979[fg]	
14 to 41 days of age													
Males	2.187	2.176	2.105	1.990	1.938	2.055	2.192	2.075	2.129	2.107	2.094	2.045	2.091[A]
Females	1.789	1.791	1.77	1.703	1.642	1.731	1.796	1.773	1.765	1.758	1.734	1.719	1.747[B]
Average	1.987[ab]	1.983[ab]	1.937[bcd]	1.847[f]	1.790[g]	1.893[def]	1.994[a]	1.924[cde]	1.945[abc]	1.933[cd]	1.914[cde]	1.882[ef]	
Body weight (kg/bird)													
41 days of age													
Males	2.563	2.545	2.486	2.366	2.323	2.434	2.553	2.438	2.509	2.493	2.472	2.430	2.468[A]
Females	2.137	2.143	2.118	2.049	2.003	2.086	2.145	2.121	2.120	2.103	2.092	2.086	2.100[B]
Average	2.350[a]	2.344[a]	2.302[abc]	2.207[d]	2.163[d]	2.260[bc]	2.349[a]	2.279[bc]	2.315[ab]	2.298[abc]	2.282[bc]	2.258[c]	

[A,B] Indicate significant sex effects (P<0.05).
[a-f] Dietary means with no common superscript are significantly different (P<0.05).

TABLE 4. Feed:gain (mortality corrected)

	Treatment												
	1	2	3	4	5	6	7	8	9	10	11	12	Sex Ave.
14 to 28 days of age													
Males	1.638	1.647	1.737	1.785	1.831	1.695	1.586	1.652	1.650	1.650	1.644	1.650	1.680^{B}
Females	1.709	1.726	1.780	1.852	1.872	1.792	1.719	1.708	1.725	1.718	1.727	1.744	1.756^{A}
Average	1.674^{de}	1.686^{d}	1.758^{c}	1.819^{b}	1.852^{a}	1.744^{c}	1.652^{e}	1.680^{d}	1.687^{d}	1.684^{d}	1.685^{d}	1.697^{d}	
28 to 41 days of age													
Males	2.113	2.115	2.148	2.215	2.326	2.205	2.114	2.099	2.181	2.180	2.256	2.315	2.189^{B}
Females	2.248	2.241	2.277	2.282	2.359	2.313	2.223	2.232	2.272	2.318	2.359	2.382	2.292^{A}
Average	2.181^{ef}	2.178^{ef}	2.212^{ed}	2.249^{cd}	2.343^{ab}	2.259^{c}	2.168^{f}	2.166^{f}	2.227^{cd}	2.249^{cd}	2.308^{b}	2.349^{a}	
14 to 41 days of age													
Males	1.893	1.897	1.954	2.010	2.086	1.962	1.866	1.890	1.933	1.929	1.968	1.986	1.948^{B}
Females	1.997	2.003	2.047	2.084	2.128	2.067	1.989	1.989	2.019	2.033	2.058	2.070	2.040^{A}
Average	1.945^{f}	1.950^{f}	2.001^{de}	2.047^{b}	2.107^{a}	2.015^{cd}	1.927^{f}	1.940^{f}	1.976^{e}	1.981^{e}	2.013^{cd}	2.028^{bc}	

^{A,B} Indicate significant sex effects ($P<0.05$).
$^{a-f}$ Dietary means with no common superscript are significantly different ($P<0.05$).

TABLE 5. Carcass, meat, bone and skin yield (%)

	Treatment												Sex	
	1	2	3	4	5	6	7	8	9	10	11	12	M	F
% of live, unfasted body weight														
EC[1]	61.9	62.4	61.7	62.8	62.7	62.9	62.2	61.8	63.0	62.4	62.4	62.8	62.6	62.3
% of Eviscerated carcass weight														
Pectoralis major	16.0	15.8	15.7	15.1	15.4	15.7	16.1	15.8	15.7	16.0	15.5	15.8	15.8	15.6
Pectoralis minor	4.4	4.2	4.3	4.0	4.2	4.1	4.3	4.3	4.2	4.3	4.3	4.2	4.1^{A}	4.4^{B}
TBM[2]	20.4	20.0	19.9	19.1	19.6	19.8	20.4	20.1	20.0	20.4	19.8	20.0	19.9	20.0
Thigh (bone in)	18.2	18.5	18.6	18.5	18.2	18.3	18.3	18.3	18.4	17.9	18.4	17.8	17.9	18.6
Thigh meat	11.5	11.8	11.5	11.4	11.3	11.0	11.6	11.7	11.6	11.6	11.8	11.5	11.5	11.6
Drum (bone in)	15.2	15.1	15.4	15.0	17.6	15.1	15.2	15.1	15.0	15.0	15.0	14.8	15.6^{A}	14.5^{B}
Drum meat	8.4^{a}	8.3^{abc}	8.5^{a}	7.8^{dc}	7.7^{d}	8.1^{abcd}	8.3^{ab}	8.2^{abc}	8.3^{abc}	7.9^{bcd}	8.0^{abcd}	8.1^{abcd}	8.4^{A}	7.9^{B}
Wings	12.6	12.4	12.8	12.7	12.9	12.7	12.7	12.6	12.8	12.8	12.6	12.7	12.6^{A}	12.8^{B}
Rack	20.8	20.6	21.2	20.5	21.2	21.0	21.2	20.8	21.2	20.9	20.9	20.6	20.6	21.2
Abdominal fat[3]	1.8^{d}	2.1^{bcd}	2.6^{ab}	2.6^{a}	2.1^{bcd}	2.1^{bcd}	2.3^{abc}	1.9^{cd}	1.8^{cd}	1.9^{cd}	2.2^{abcd}	2.4^{ab}	2.1	2.1
Total meat[4]	40.2^{a}	40.1^{a}	39.9^{ab}	38.4^{c}	38.6^{bc}	39.0^{abc}	40.4^{a}	40.1^{a}	39.8^{ab}	39.9^{ab}	39.7^{abc}	39.6^{abc}	39.8	39.4
Total bone[5]	15.6	15.8	16.9	16.0	15.9	17.2	15.8	15.6	15.8	15.9	15.6	15.8	16.3	15.7
Total skin[6]	9.8	10.3	10.9	10.3	10.5	10.2	10.0	10.3	9.6	9.4	10.3	10.4	9.7^{B}	10.6^{A}

[1] EC – eviscerated carcass. [2] TBM - Total breast meat = pectoralis major + pectoralis minor.
[3] Abdominal fat = fat adhering to admonimal wall after mechanical evisceration.
[3] Total meat = thigh meat + drumstick meat + total breast meat. [4] Total bone = thigh bones + drumstick bones + keel.
[5] Total skin = thigh skin + drumstick skin + breast skin.
[A,B] Indicate significant sex effects ($P<0.05$).
[a-f] Dietary means with no common superscript are significantly different ($P<0.05$).

Experiment 6 - 9

TABLE 6. Feed + chick cost, $/kg shipped (november, 1995)

	Treatment												
	1	2	3	4	5	6	7	8	9	10	11	12	Mean
Pullets	0.777	0.750	0.770	0.765	0.828	0.795	0.761	0.769	0.760	0.788	0.774	0.806	0.779
Cockerels	0.721	0.729	0.739	0.739	0.810	0.773	0.721	0.741	0.728	0.753	0.741	0.771	0.747
Average	0.749	0.74	0.755	0.752	0.819	0.784	0.741	0.755	0.744	0.771	0.758	0.789	

Average Body Weights (kg)

	Treatment												
	1	2	3	4	5	6	7	8	9	10	11	12	Sex Ave.
14 Days of Age													
Males	.377	.369	.381	.376	.385	.380	.360	.363	.381	.386	.378	.385	.377^{A}
Females	.350	.351	.350	.346	.362	.354	.349	.348	.355	.345	.358	.367	.353^{B}
Average	.363	.360	.365	.361	.374	.367	.355	.356	.368	.365	.368	.376	
28 Days of Age													
Males	1.361	1.342	1.323	1.303	1.302	1.329	1.361	1.307	1.357	1.360	1.348	1.364	1.338^{A}
Females	1.164	1.179	1.151	1.123	1.133	1.163	1.169	1.163	1.169	1.170	1.175	1.195	1.174^{B}
Average	1.262^{abc}	1.261^{abcd}	1.237^{cde}	1.213^{e}	1.217^{e}	1.246^{bcd}	1.265^{ab}	1.235^{de}	1.263^{abc}	1.265^{ab}	1.261^{abcd}	1.279^{a}	
41 Days of Age													
Males	2.563	2.545	2.486	2.366	2.323	2.434	2.553	2.438	2.509	2.493	2.472	2.430	2.468^{A}
Females	2.137	2.143	2.118	2.049	2.003	2.086	2.145	2.121	2.120	2.103	2.092	2.086	2.100^{B}
Average	2.350^{a}	2.344^{a}	2.302^{abc}	2.207^{d}	2.163^{d}	2.260^{bc}	2.349^{a}	2.279^{bc}	2.315^{ab}	2.298^{abc}	2.282^{bc}	2.258^{c}	

EXPERIMENT 7

INTERACTION OF WHEAT MICRONIZATION AND CULTIVAR ON ITS FEEDING VALUE FOR BROILERS

Z. Y. NIU, H. L. CLASSEN, and T. A. SCOTT

ABSTRACT

Three experiments were conducted to investigate the interaction between micronization and cultivar of wheat on grain chemical composition and feeding value for chickens. Whole grain feeding was evaluated in one experiment. Dietary enzyme was used in the rest of experiments to study its interaction with micronization and genotype of wheat. Wheats (Genesis, Kyle and Katepwa) were micronized at 100°C for 50 s and incorporated into the broiler diets. Micronization improved overall feed efficiency, but did not always increase body weight. **When feeding whole grain to birds, micronization improved feed efficiency from 21 - 42 d and 0 - 42 d, and did not affect final body weight.** Micronization reduced early growth rate for all cultivars regardless of wheat form in the diets. Micronization did not impact AME and digesta viscosity. Kyle cultivar had a higher dietary AME and a lower digesta viscosity, and resulted in better feed efficiency and weight gain than either Genesis or Katepwa (Experiments 2 and 3). Enzyme increased weight gain, feed efficiency and dietary AME, and decreased digesta viscosity. In summary, micronization improved feed efficiency of broilers fed different cultivars of wheat when fed in a mash or whole form. Despite the uniform response for feed efficiency, an interaction between micronization and cultivar for digesta viscosity suggests that wheat samples can response differently to micronization treatment.

INTRODUCTION

Recent research using Western Canadian cultivars examined the effect of genotype and growing environment on wheat feeding value and chemical composition (Classen *et al.*, 1995; Scott *et al.*, 1998; Scott *et al.*, 1999). Nine cultivars, selected to represent a wide range of genotypes, were grown on multiple sites for two consecutive years. Both genotype and growing condition had a significant effect on diet AME and grain chemical composition (Classen *et al.*, 1995). Scott *et al.* (1999) studied the effect of cultivar on the feeding value of Western Canadian wheat. They found that Durum varieties had higher AME than did Canadian Prairie Spring and Hard Red Spring cultivars, and resulted in better broiler performance partly due to lower digesta viscosity. Variability in wheat quality was primarily attributed to the level of soluble non-starch polysaccharides (NSPs) but much of the variability in AME was unexplained by chemical composition. NSPs are present in grain cell walls and are known to possess anti-nutritional effects that reduce nutrient utilization and, consequently, broiler performance (Bedford and Classen, 1992; Choct and Annison, 1992). Dietary microbial enzyme supplements containing endo-xylanase activity are known to reduce the viscous nature of arabinoxylans, which are a major portion of the grain NSPs. In turn, the hydrolysis of arabinoxylans improves nutrient utilization from wheat-based diets and also improves broiler production characteristics (Bedford and Classen, 1992; Marquardt *et al.*, 1994).

Various processing techniques have been used to improve the nutritional value of feed ingredients. Included among these techniques are those that apply heat, such as micronization. Previous research with wheat indicated that the optimum micronization temperature is between 90 and 105°C (Niu *et al.*, 1999). They found that micronization generally increased AME value and feed efficiency, and sometimes increased body weight gain.

Previous research on wheat micronization has failed to take into account the variability of feeding value among grain genotypes. Therefore, the primary objective of this research was to examine the interaction between wheat cultivar and micronization in broiler production and nutrient retention studies. Three cultivars were selected with high (Kyle), intermediate (Katepwa) and low feeding value (Genesis) based on the research of Scott *et al.* (1999). Feeding whole grain can reduce milling costs and possibly reduce coccidiosis challenge without loss of performance in broiler production (Cumming, 1992; Rose *et al.*, 1995; Bennett *et al.*, 1995), but may benefit from heat treatment. A second objective was to examine the impact of micronization on the feeding value of whole grain.

MATERIALS AND METHODS

Experimental Design

Three experiments were conducted to investigate the effects of micronization on the feeding value of wheat cultivars. The three cultivars of wheat used in this research were Genesis (Canadian Prairie Spring, CPS), Kyle (Durum, DUR) and Katepwa (Hard Red Spring, HRS). The three cultivars of wheat were purchased as pedigree seed and micronized for 50 s at 100°C without tempering or flaking at InfraReady Products Ltd., Saskatoon, SK, Canada. Wheat treated in the same way but fed in more than one experiment was from the same sample.

Experiment 1 was a 2×3×2 factorial design which examined the main effects of wheat micronization (without and with), cultivar (Genesis, Kyle and Katepwa) and the use of a dietary microbial enzyme source (0 or 0.1%; Avizyme 1300[1]) containing endoxylanase activity. Experiment 2 was designed as a 2×2 factorial with the main effects of wheat micronization (without and with), and cultivar (Genesis and Kyle) when a portion of the wheat was fed in the whole grain form (10% in starter, and 50% in grower). Both ground and whole grain wheat were from same sources, and treatments of wheat were the same as those described in Experiment 1. In Experiment 3, the effect of wheat micronization, cultivar and dietary enzyme on dietary AME and broiler performance were studied using a 2×3×2 factorial design. The sources and treatments of wheat were as outlined above.

[1] Finnfeeds International, Malborough, Wiltshire, UK, SN8 1XN.

Experimental Diets

Wheat was hammer milled through a 3 mm screen prior to incorporation into mash diets (Table 1). All diets were formulated to be isoenergetic and isonitrogenous. In Experiment 2, diets were fed without a dietary enzyme, and included 10% and 50% whole wheat in the starter and finisher diets, respectively. In Experiment 3, wheat and isolated soy protein based-diets were fed with and without a dietary enzyme (Table 2).

Broiler Management

Commercial day-old male broiler chicks (Peterson×Shaver) were housed in straw-litter pens in six (Experiment 1) or three (Experiment 2) environmentally controlled rooms with 12 pens per room. Forty-five birds were assigned to each pen and six pens to each treatment. The birds were reared under an increasing lighting program (Classen and Riddell, 1989). Initial room temperature was 32°C, and was then gradually decreased according to usual brooding practice. Supplemental heat was provided by hot water pipes.

Care of the birds followed the guidelines of the Canadian Council of Animal Care (1993), and the protocol had been approved by the Animal Care Committee at the University of Saskatchewan. Birds were fed on starter and finisher diets from 0 to 21 d and 21 to 42 d of age, respectively. Body weight, on a pen basis, was determined at 0, 21 and 42 d, and feed intakes were recorded for the corresponding periods. Gain to feed ratios were calculated using the above data, with a correction for mortality in which the weight of the dead birds was included in the bird weight at the end of each period. Dead birds were recorded daily and weighed.

Experiment 3 was conducted at Pacific Agri-Food Research Centre by Agriculture and Agri-Food Canada. Day-old male broiler chicks (Peterson×Arbor Acres) were randomly housed in wire-floored battery pens. Six birds were assigned to each pen and four pens to each treatment. From 1 to 4 d of age, all chicks were fed a standard broiler starter diet providing 22% protein and 2,900 kcal ME/kg. From 4 to 17 d of age, all birds were fed experimental diets containing 0.8% celite and 0.3% Cr_2O_3 to allow the estimation of AME. Body weight, on a pen basis, was determined on d 17 and feed intakes were recorded. Gain:feed ratios were calculated using the above data with a correction for mortality.

Digesta Collection and Determination of Digesta Viscosity

The viscosity of intestinal samples was examined in Experiment 3. On d 17, four birds from each pen were killed by cervical dislocation and the intestinal tract was excised. Ileal digesta from two birds was combined for chemical analysis. Digesta from the upper small intestine (duodenum and jejunum) of another two birds was pooled, placed into centrifuge tubes, centrifuged at 3,000 rpm and the supernatant collected. The viscosity of the supernatant was determined using a Brookfield Viscometer LVDVII+CP (Scott *et al.*, 1998).

Analyses of Grain, Feed and Faeces

A procedure (No. 975.06) from the Association of Official Analytical Chemists (AOAC, 1990) was used to determine the nitrogen content of wheat. Crude protein was determined with a Tecator Digestion system-20 (model 1015) and a Tecator Kjeltec Analyzer (model 1030). Protein solubility of wheat samples was determined as the percent protein solubilized in 0.2% KOH (Araba and Dale, 1990). The starch content of wheat samples was determined according to the procedure of Salmonsson *et al.* (1984), using thermostable α- amylase and amyloglucosidase. *In vitro* grain viscosity was determined according to the procedures described by Bedford and Classen (1993). The dietary fibre content of grain was determined using the methods described by Englyst and Hudson (1987) and Englyst (1989). In this procedure, starch was removed enzymatically and dietary fibre measured in terms of constituent sugars, which were measured by gas chromatography (Varian Star 3400 CX).

In Experiment 3, 0.8% celite and 0.3% Cr_2O_3 were added to the diets to permit the estimation of AME. Excreta samples were collected for a 24 h period at 16 d of age. Feed, excreta and ileal digesta were analyzed for acid insoluble ash marker described by Scott *et al.* (1998) and GE using standard procedures (AOAC, 1990). The AME of the diets was calculated as: $AME\ (kcal/kg_{diet}) = GE_{diet} - (GE_{excreta} \times Marker_{diet}/Marker_{excreta})$.

Statistical Analysis

Body weight gain, feed efficiency, AME and digesta viscosity were analyzed using factorial designs (Steel and Torrie, 1980) with the pen as the replication unit (SAS, 1989). Duncan's multiple range test was used to detect differences among group means. Differences were considered significant when $P \leq 0.05$, unless otherwise specified.

RESULTS

Chemical analyses were completed in duplicate for each sample, with 3% error accepted between duplicate for all analyses except for *in vitro* viscosity where 5% error was accepted. The results were not subjected to statistical analysis.

Micronization of wheat caused only minor effects on its chemical and physical characteristics. An exception was *in vitro* viscosity, which was slightly increased (Table 3). Micronization slightly increased soluble fibre in Kyle and decreased soluble fibre in Katepwa. The wheat samples varied considerably in the measured parameters. Genesis had higher starch, lower protein (total and soluble) and a higher soluble fibre content than either Kyle or Katepwa. Kyle was similar in composition to Katepwa, but had relatively lower soluble fibre and *in vitro* viscosity than Genesis and Katepwa.

There were no significant interactions between the main effects in Experiment 1, therefore, only the main effects were discussed. Micronization had a negative effect on body weight gain from 0 to 21 d of age for all three cultivars (Figure 1), but did not affect overall weight gain. Micronization improved feed efficiency from 21 to 42 d of age and

for the entire experiment (P=0.07), although it had no effect on feed efficiency from 0 to 21 d of age (Table 4). Cultivar did not affect final body weight, although the Kyle treatment gained more weight than did the Genesis treatment from 22 to 42 d of age. Both Kyle- and Katepwa-fed birds had better feed efficiency than that fed Genesis from 0 to 21, 21 to 42 and 0 to 42 d of age. The overall feed efficiency ranking was Kyle > Katepwa > Genesis, with all differences statistically significant. Dietary enzyme increased weight gain and improved feed efficiency throughout the experiment. Bird death loss was 4.1%, and not affected by any main effects.

In Experiment 2, micronization of wheat had a negative effect on weight gain from 0 to 21 d of age for both Genesis and Kyle, but the negative effect disappeared by trial end (Table 4). Similar to Experiment 1, micronization improved feed efficiency from 21 to 42, and 0 to 42 d of age. Kyle-fed broilers were similar in weight gain at 21 d of age to that fed Genesis; feeding Kyle during this period resulted in improved feed efficiency in comparison to Genesis. Kyle-fed birds grew faster and more efficiently than birds fed Genesis from 21 to 42 d and 0 to 42 d of age. There were no interactions between micronization and wheat cultivar. Bird mortality rate was 4.5%, and not affected by any main effects.

Micronization increased body weight and improved feed efficiency, but did not affect AME in Experiment 3 (Table 5). Feeding either Kyle or Katepwa resulted in a higher body weight than did feeding Genesis; and Kyle-fed birds utilized feed more efficiently than those fed either Genesis or Katepwa. In addition, Kyle had a higher AME than either Genesis or Katepwa. The effects of wheat micronization on digesta viscosity were cultivar dependent, with a relatively large increase for Genesis, a small increase for Kyle, and a substantial decrease for Katepwa. Enzyme decreased digesta viscosity for all wheat cultivars, but the response was least for Kyle where values without enzyme addition were already quite low. Dietary enzyme improved bird performance and increased dietary AME. The three-way interaction between micronization, wheat cultivar, and enzyme addition for digesta viscosity was primarily a reflection of the differential cultivar response to micronization and enzyme.

DISCUSSION

There were no significant interactions between micronization and cultivar for performance and AME in any of the experiments. The only interactions observed were for digesta viscosity, where Katepwa was significantly different than the other cultivars, particularly Genesis. The effect of micronization on digesta viscosity appeared to be cultivar dependent with a relatively large increase for Genesis, a small increase for Kyle and a substantial decrease for Katepwa. This could be due to the wheat soluble dietary fibre content and changes induced by micronization. In terms of soluble fibre content, Kyle had the lowest, Katepwa intermediate, and Genesis the highest level. Furthermore, micronization increased soluble fibre for both Genesis and Kyle, but decreased it for Katepwa. Katepwa might be more sensitive to the heat treatment, and cell wall fibre could form complex with other grain components at a relatively low temperature. This reasoning is also supported by the non-significant interaction (P=0.12) between micronization and cultivar for AME (Figure 2). Micronization slightly increased the AME for Kyle, did not affect AME for Genesis, but decreased it for Katepwa. Micronization resulted in reduced early growth rate in both Experiment 1

and Experiment 2, and the reduction in early growth rate was consistent regardless of cultivar. It was possible that young broilers were having difficulty digesting feeds because of higher digesta viscosity as seen from *in vitro* viscosity. Contrary to these results, micronization did not show any negative effect in Experiment 3. The discrepancy between experiments could result from different levels of wheat in the diets.

The effects of micronization on the feeding value of wheat were very similar in Experiments 1 and 2 with the primary effect of improved feed efficiency. This indicates that micronization benefits energy utilization regardless whether grain is fed in a whole or mash form. The improvement in broiler performance is similar to that observed in previous work (Niu *et al.*, 1999). Birds fed micronized rye-based diets with enzyme addition had higher body weight gain (Teitge *et al.*, 1991), and broilers fed micronized peas grew faster and had a better feed efficiency (Igbasan and Guenter, 1996). Douglas *et al.* (1991) reported that micronization of corn and low- and high-tannin sorghum improved the weight gain and feed efficiency of broilers. Micronization of hulless barley also improved performance of growing pigs (Huang *et al.*, 1998). Micronization could cause a heat-induced conformational change in the pentosan complex (Teitge *et al.*, 1991), i.e. break down cell walls, releasing nutrients, and allowing greater accessibility to enzyme attack, which would contribute to the improvements in body weight and feed efficiency. It was also speculated that fore gut nutrient absorption was higher and hind gut microbial fermentation lower for micronized than for non-micronized wheat-based diets. Therefore, micronization improved broiler performance without changing AME. This might be especially true for older birds, which was demonstrated by the compensation growth from 21 to 42 d of age.

The wheat used in these experiments represented three cultivars which had been previously shown to have different feeding value for broiler chicks (Classen *et al.*, 1995; Scott *et al.*, 1999). The results from this research supported the ranking established by Scott *et al.* (1999). They found that DUR wheat had higher AME values and lower digesta viscosity than CPS and HRS, and resulted in better chick performance. So despite the fact that our research only used single sample of each cultivar, the results confirmed their relative feeding value.

Apparent interactions for digesta viscosity between micronization and cultivar, cultivar and enzyme, and among the three main effects reflected the different responses of wheat cultivars toward micronization and dietary enzyme addition (Table 6). Micronization significantly increased the digesta viscosity of Genesis-fed birds, Kyle slightly, but decreased it for Katepwa. Enzyme decreased digesta viscosity, but the degree of change for Kyle-fed birds was much less than those of Genesis and Katepwa. Furthermore, digesta viscosity of Kyle-fed birds without dietary enzyme was already very low.

In conclusion, micronization improved feed efficiency and sometimes increased body weight despite the reduced early growth rate for all cultivars. Wheat genotype affected broiler performance, although the cultivars used in this research were only represented by one sample. Micronizing wheat resulted in improved feed efficiency regardless of form in which it was fed (mash or whole grain). Enzyme increased energy utilization,

decreased digesta viscosity, and, therefore, increased body weight gain and feed efficiency.

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TABLE 1. Composition (%) of diets (Experiments 1 and 2)

Ingredients	Genesis		Kyle		Katepwa	
	Starter	Finisher	Starter	Finisher	Starter	Finisher
Wheat	61.0	65.3	69.4	74.6	69.4	74.6
Soybean meal	29.4	24.8	20.8	16.0	20.8	16.0
Meat meal	5.0	5.0	5.0	5.0	5.0	5.0
Canola oil	1.98	2.63	1.80	2.03	1.80	2.03
Limestone	1.04	0.96	1.09	0.97	1.09	0.97
Dicalcium phosphate	0.65	0.51	0.87	0.52	0.87	0.52
Salt	0.25	0.25	0.27	0.24	0.27	0.24
DL-methionine	0.18	0.05	0.27	0.14	0.27	0.14
Avizyme 1300[1]	0.10	0.10	0.10	0.10	0.10	0.10
Coxistac[2]	0.10	0.10	0.10	0.10	0.10	0.10
Stayfac[3]	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin premix[4]	0.10	0.10	0.10	0.10	0.10	0.10
Mineral premix[5]	0.07	0.07	0.07	0.07	0.07	0.07
Choline chloride	0.08	0.08	0.08	0.08	0.08	0.08
Total	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis						
Crude protein (%)	22.0	20.0				
ME (kcal/kg)	2950	3000				
Calcium (%)	1.00	0.90				
Avail. phosphorus (%)	0.45	0.40				
Lysine (%)	1.20	1.10				
Methionine (%)	0.57	0.42				
MET & CYS (%)	0.90	0.73				

[1]Finnfeeds International, Marlborough, Wiltshire, United Kingdom, SN8 1XN. No enzyme in Experiment 2.

[2]Active ingredient is salinomycin sodium at 60 g kg^{-1} Coxistac (Pfizer Canada Inc., Animal Health Division, Pointe-Claire, Quebec, Canada, H9R 4V2).

[3]Active ingredient is virginiamcin at 2.2 g kg^{-1} Stafac (SmithKline Beecham Animal Health, Mississauga, Ontario, Canada, L5L 4X4).

[4]Vitamin premix, supplied the following per kg of diet: vitamin A, 15,700 IU; vitamin D_3, 3,140 IU; vitamin E, 40 IU; vitamin K, 2.5 mg; thiamine, 2.5mg; riboflavin, 10 mg; niacin, 84 mg; pyridoxine, 4 mg; vitamin B_{12}, 0.016 mg; pantothenic acid, 15.43 mg; folic acid, 1.1 mg; and biotin, 0.14 mg.

[5]Mineral premix, supplied the following per kg of diet: iron, 56 mg; zinc, 77 mg; manganese, 94.5 mg; copper, 7 mg; iodine, 0.91 mg; and selenium, 0.07 mg.

TABLE 2. Composition (%) of diets (Experiment 3)

Ingredients	Enzyme -	Enzyme +
Wheat	80.000	79.900
Tallow	2.000	2.000
Isolated soy protein	11.512	11.512
Corn gluten meal	1.100	1.100
L-Lysine-HCl	0.154	0.154
DL-Methionine	0.044	0.044
Avizyme 1300[1]		0.150
Vitamin-mineral premix[2]	4.090	4.090
Celite	0.800	0.800
Cr_2O_3	0.300	0.300
Total	100.000	100.000
Analyzed composition		
DM (%)	90.5	90.5
Crude protein (%)	22.4	22.4
AME (kcal/kg)[3]	3020	3150
Acid insoluble ash (%)	1.23	1.23

[1]Finnfeeds International, Marlborough, Wiltshire, United Kingdom, SN8 1XN.
[2]Supplies/kg of diet: vitamin A, 9,000 IU; vitamin D_3, 1,500 IU; vitamin E 10 IU; vitamin K, 0.5 mg; vitamin B_{12}, 0.007 mg; thiamin, 0.4 mg; riboflavin, 6 mg; folic acid, 1 mg; biotin, 0.15 mg; niacin, 35 mg; pyridoxine, 4 mg; choline chloride,1,000 mg; DL-methionine,1184 mg; ethoxyquin, 0.125 mg; sodium, 0.8mg; manganese, 22 mg; copper, 2 mg; selenium, 0.1 mg; iodine, 0.35 mg; and zinc, 20 mg.
[3]Wheat AME is assumed to be 3000 kcal/kg without enzyme and 3150 kcal/kg with enzyme when formulating diets; analyzed results confirmed that enzyme increased wheat AME.

TABLE 3. Effect of micronizing and cultivar on the chemical and physical characteristics of wheat

	Cultivar					
	Genesis		Kyle		Katepwa	
	WOM[1]	WM[1]	WOM	WM	WOM	WM
Starch (% of DM)	66.3	68.8	63.1	61.6	62.2	62.8
Gelatinized starch (%)[2]	1.7	1.0	1.9	1.3	0.9	1.0
Protein						
Total (% of DM)	10.7	11.3	16.1	16.2	16.0	16.2
Soluble[3]	92.6	93.3	96.2	96.9	96.6	96.8
Dietary fibre (% of DM)						
Total	9.8	10.3	9.4	9.2	10.6	10.1
Soluble	3.0	3.1	1.5	1.9	2.8	2.1
Pentosans (% of DM)						
Total	6.4	6.6	6.2	6.1	6.8	6.8
Soluble	2.2	2.2	1.2	1.5	2.2	2.0
In vitro viscosity (cP)	3.7	4.1	2.0	2.3	3.8	4.5

[1]WOM - without micronization; WM - with micronization.
[2]Gelatinized starch/starch×100.
[3]Soluble protein (% of DM) / Total Protein (% of DM) ×100.

TABLE 4. Effects of wheat micronization, wheat cultivar and dietary enzyme supplementation on broiler chicken performance (Experiments 1 and 2)

	Weight gain (kg)			Feed efficiency (gain/feed)		
	0-21 d	21-42 d	0-42 d	0-21 d	21-42 d	0-42 d
Experiment 1						
Micronization						
Without	0.599a	1.660	2.259	0.733	0.532^{b}	0.574
With	0.588b	1.653	2.241	0.731	0.537^{a}	0.578
Pooled SEM	0.0037	0.0074	0.0098	0.0023	0.0015	0.0013
Cultivar						
Genesis	0.595	1.639^{b}	2.234	0.717^{b}	0.512^{b}	0.555^{c}
Kyle	0.591	1.676^{a}	2.267	0.748^{a}	0.549^{a}	0.590^{a}
Katepwa	0.594	1.653^{ab}	2.247	0.730^{a}	0.545^{a}	0.584^{b}
Pooled SEM	0.0046	0.0091	0.0121	0.0028	0.0018	0.0016
Enzyme						
Without	0.587^{b}	1.646	2.233^{b}	0.723^{b}	0.523^{b}	0.565^{b}
With	0.600^{a}	1.667	2.267^{a}	0.741^{a}	0.546^{a}	0.588^{a}
Pooled SEM	0.0037	0.0074	0.0098	0.0023	0.0015	0.0013
Source of variation			*Probability*			
Micronization	0.05	0.48	0.20	0.73	0.02	0.07
Cultivar	0.85	0.01	0.13	0.00	0.00	0.00
Enzyme	0.01	0.06	0.02	0.00	0.00	0.00
Experiment 2						
Micronization						
Without	0.607^{a}	1.654	2.261	0.738	0.529^{b}	0.573^{b}
With	0.584^{b}	1.683	2.267	0.732	0.545^{a}	0.584^{a}
Pooled SEM	0.0064	0.0127	0.0163	0.0035	0.0037	0.0028
Cultivar						
Genesis	0.599	1.639^{b}	2.238^{b}	0.723^{b}	0.515^{b}	0.559^{b}
Kyle	0.593	1.697^{a}	2.290^{a}	0.748^{a}	0.558^{a}	0.598^{a}
Pooled SEM	0.0064	0.0127	0.0163	0.0035	0.0037	0.0028
Source of variation			*Probability*			
Micronization	0.02	0.13	0.79	0.18	0.01	0.02
Cultivar	0.48	0.00	0.04	0.00	0.00	0.00

[a, b] Means within a column and main effect with different superscripts are significantly different ($P \leq 0.05$).

TABLE 5. Effects of wheat micronization, wheat cultivar and dietary enzyme supplementation on broiler performance, diet AME and digesta viscosity (Experiment 3)

	Body weight (g) 17 d	Gain: feed 17 d	AME (kcal/kg DM) 16 d	Digesta viscosity (cP) 17 d
Micronization				
Without	415[b]	0.695[b]	3550	11.5
With	428[a]	0.710[a]	3537	13.0
Pooled SEM	4.3	0.0049	30.5	3.62
Cultivar				
Genesis	410	0.668[c]	3530[b]	18.3[a]
Kyle	427	0.731[a]	3650[a]	4.7[b]
Katepwa	427	0.713[b]	3451[b]	13.6[a]
Pooled SEM	6.4	0.0125	29.6	3.43
Enzyme				
Without	408[b]	0.690[b]	3481[b]	19.5[a]
With	434[a]	0.716[a]	3606[a]	5.0[b]
Pooled SEM	4.7	0.0077	28.0	2.32
Source of variation		*Probability*		
Micronization (M)	0.05	0.02	0.70	0.52
Cultivar (C)	0.06	0.00	0.00	0.00
Enzyme (E)	0.00	0.00	0.00	0.00
M × C				0.02
C × E				0.01
M × C × E				0.02

[a, b] Means within a column and main effect with different superscripts are significantly different ($P \leq 0.05$).

TABLE 6. Interactions between micronization, cultivar and dietary enzyme in digesta viscosity

Interactions: micronization × cultivar (P=0.02); cultivar × enzyme (P=0.01)				
	Micronization		Enzyme	
Cultivar	-	+	-	+
Genesis	12.7	24.0	30.0	6.6
Kyle	4.4	5.0	5.9	3.5
Katepwa	17.3	9.9	22.5	4.7

Interaction: micronization × cultivar × enzyme (P=0.02)				
	Micronization -		Micronization +	
Cultivar	Enzyme -	Enzyme +	Enzyme -	Enzyme +
Genesis	19.3	6.1	40.7	7.2
Kyle	5.6	3.2	6.1	3.8
Katepwa	30.3	4.3	14.8	5.1

E. fPersonnel

SALARIES		
Technical (100% time)		
Niu, Z.Y	Sept. 1, 1997 – Jan. 1999	$38,992.01
Semenoff, K.	Nov.-Dec. 1997	$ 2,500.00
Drimmie, A.	Nov. 1, 1997 – Nov. 30, 1997	$ 2,726.20
Yobb, D.	March 1999 – April 1999	$ 5,279.42
TOTAL		$49,497.63

F. Equipment

NONE

G. Project Developed Materials

Model for calculation of body weight and feed efficiency of broiler chicken and turkey flocks fed whole grain with no dilution (Appendix A)

H. Project Photos

NONE

I. Acknowledgement

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J. Expense Statement

SEE ATTACHED

K. Communication of Results

Scientific conference presentations (3)
Scientific papers published or accepted for publication (2)
Presentation and written paper to feed industry (Western Nutrition Conference)
Producer meting presentations (10)
National turkey producer meeting (1)
Popular press articles (2)

Appendix A

Calculation of Body Weight Gain and Feed Efficiency of Broiler Chicken and Turkey Flocks Fed Whole Grain With No Dilution

Calculating Performance of Broiler Chickens on Whole Grain Feeding Programs

Step 1.

Collect the following information for typical performance for the producer and feed mill that you are dealing with for diets containing no whole grain:

1. Feed consumed per kg shipped: Starter: _____ Grower: _____ Finisher: _____
2. Market Body Weight : _____ kg

Step 2. Decide how much whole grain you want in each ration in the first 6 weeks.

Step 3. Calculate the cumulative whole grain intake for the birds based on the levels of whole grain that will be fed.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Starter	_____	* ____/100%	= _____
Grower	_____	* ____/100%	= _____
Finisher	_____	* ____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100%
= _____ %

Step 4. Using Table 12 at the bottom of the page, look up the relative gain and feed:gain corresponding to the cumulative level of whole grain that you plan to use in the flock.

Relative Body Weight Gain = _____ %
Relative Feed:Gain = _____ %

Step 5: Calculate the expected body weight and feed efficiency for the whole feeding program chosen:

Adjusted Body Weight
= Body Weight * (Relative Body Weight% / 100%)
= _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped
= Feed/kg shipped * (Relative Feed:Gain% / 100%)
= _____ * (_____ / 100%) = _____

Table 12. Body Weight Gain and Feed:Gain of Broiler Chickens Fed Different Levels of Whole Grain Relative to Birds Fed Just Crumbles/Pellets

Cumulative Whole Grain %	Performance Relative to Birds Fed Just Crumbles and Pellets		Cumulative Whole Grain %	Performance Relative to Birds Fed Just Crumbles and Pellets	
	Body Weight Gain	Feed:Gain		Body Weight Gain	Feed:Gain
0%	100.0	100.0	30%	98.7	101.8
5%	99.9	100.3	35%	98.3	102.1
10%	99.8	100.6	40%	97.9	102.4
15%	99.5	100.9	45%	97.3	102.7
20%	99.3	101.2	50%	96.7	103
25%	99.0	101.5	55%	96.1	103.5

Note: The relative performance index is based on feeding programs where the level of whole grain is started at a low level and then increased as the birds grow older, e.g. 5% in starter, 20% in grower and 35% in finisher. If the level is decreased as the birds grow older, the relative performance could be inaccurate, e.g. 35% in starter, 20% in grower and 5% in finisher.

Example 1: Calculating Performance of Broiler Chickens on Whole Grain Feeding Programs

Step 1.

Collect the following information for typical performance for the producer and feed mill that you are dealing with for diets containing no whole grain:

1. Feed consumed per kg shipped: Starter: _____ Grower: _____ Finisher: _____
2. Market Body Weight : _____ kg

Step 2. Decide how much whole grain you want in each ration in the first 6 weeks.

Step 3. Calculate the cumulative whole grain intake for the birds based on the levels of whole grain that will be fed.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Starter	_____	* ____/100%	= _____
Grower	_____	* ____/100%	= _____
Finisher	_____	* ____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100%
= _____ %

Step 4. Using Table 1 at the bottom of the page, look up the relative gain and feed:gain corresponding to the cumulative level of whole grain that you plan to use in the flock.

Relative Body Weight Gain = _____ %
Relative Feed:Gain = _____ %

Step 5: Calculate the expected body weight and feed efficiency for the whole feeding program chosen:

Adjusted Body Weight
= Body Weight * (Relative Body Weight% / 100%)
= _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped
= Feed/kg shipped * (Relative Feed:Gain% / 100%)
= _____ * (_____ / 100%) = _____

Table 1. Body Weight Gain and Feed:Gain of Broiler Chickens Fed Different Levels of Whole Grain Relative to Birds Fed Just Crumbles/Pellets

Cumulative Whole Grain %	Performance Relative to Birds Fed Just Crumbles and Pellets		Cumulative Whole Grain %	Performance Relative to Birds Fed Just Crumbles and Pellets	
	Body Weight Gain	Feed:Gain		Body Weight Gain	Feed:Gain
0%	100.0	100.0	30%	98.7	101.8
5%	99.9	100.3	35%	98.3	102.1
10%	99.8	100.6	40%	97.9	102.4
15%	99.5	100.9	45%	97.3	102.7
20%	99.3	101.2	50%	96.7	103
25%	99.0	101.5	55%	96.1	103.5

Note: The relative performance index is based on feeding programs where the level of whole grain is started at a low level and then increased as the birds grow older, e.g. 5% in starter, 20% in grower and 35% in finisher. If the level is decreased as the birds grow older, the relative performance could be inaccurate, e.g. 35% in starter, 20% in grower and 5% in finisher.

Calculating Performance of Turkey Flocks on Whole Grain Feeding Programs

Step 1. Collect the following information for typical performance for the producer and feed mill that you are dealing with for diets containing no whole grain:

a. Feed consumed per kg shipped:

Pre-Starter: _____ Starter: _____ Grower 1: _____ Grower 2: _____ Finisher: _____

b. Body Weight, kg:

6 weeks old: _____ 10 weeks old: _____ Market age: _____

Step 2. Decide how much whole grain you want in each ration in the first 6 weeks.

Step 3. Calculate the cumulative whole grain intake in the first 6 weeks based on the levels of whole grain that will be fed.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
PreStart	_____	* _____/100%	= _____
Starter	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100%
= _____ %

Step 4. Using Table 13 on page 18, look up the relative gain and feed:gain corresponding to the cumulative level of whole grain that you plan to use in the first 6 weeks.

Relative Body Weight Gain = _____ %
Relative Feed:Gain = _____ %

Step 5: Calculate the expected body weight and feed efficiency at 6 weeks of age for the whole feeding program chosen:

Adjusted Body Weight $_{6\ weeks}$
= Body Weight $_{6\ weeks}$ * (Relative Body Weight $_{6\ weeks}$/100%)
= _____ * (_____ / 100%) = _____
Adjusted Feed/kg shipped $_{0\ to\ 6\ weeks}$
= Feed/kg shipped $_{0\ to\ 6\ weeks}$ * (Relative Feed:Gain / 100%)
= _____ * (_____ / 100%) = _____

Step 6. Decide how much whole grain you want in each ration from 6 to 10 weeks of age.

Step 7. Calculate the cumulative whole grain from 6 to 10 weeks of age.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100% = _____ %

Step 8. Calculate typical body weight gain on pellets without whole grain from 6 to 10 weeks

Body Weight Gain $_{6\ to\ 10\ weeks}$
= Body Weight $_{10\ weeks}$ - Body Weight $_{6\ weeks}$
= _____ - _____ = _____

Step 9. From the table on page 18, find the relative performance from 6 to 10 weeks of age corresponding to the average level of whole grain calculated in Step 6. Note, if you increased whole grain usage by 20% or more from 6 to 10 weeks compared to 0 to 6 weeks, e.g. increasing from an average of 30% to 50%, then use the relative performance expected at 0 to 6 weeks of age for that level of whole grain.

Relative Body Weight Gain $_{6\ to\ 10\ weeks}$ = _____ %
Relative Feed:Gain $_{6\ to\ 10\ weeks}$ = _____ %

Step 10. Calculate the body weight gain, feed/kg shipped, and from 6 to 10 weeks of age:

Adjusted Body Weight Gain
= Body Weight Gain $_{6 \text{ to } 10 \text{ weeks}}$ * (Relative Body Weight% / 100%) = _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$
= Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$ * (Relative Feed:Gain% / 100%) = _____ * (_____ / 100%) = _____

Step 11. Decide how much whole grain that you want to feed in each diet from 10 weeks of age to market.

Step 12. Calculate the cumulative whole grain intake from 10 weeks of age to market.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Finisher	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ = _____

Step 13.

Calculate typical body weight gain on pellets without whole grain from 10 weeks to market age:

Body Weight Gain $_{10 \text{ weeks to market}}$
= Body Weight $_{\text{market}}$ - Body Weight $_{10 \text{ weeks}}$
= _____ - _____ = _____

Step 14. From the table on page 19, find the relative performance from 10 weeks of age to market corresponding to the average level of whole grain calculated in Step 14:

a. If you have been feeding whole grain since at least 3 weeks of age and have not increased the level of whole grain by 20% or more compared to 6 to 10 weeks of age, e.g. from 30% to 50% of the diet, then assume that weight gain and feed:gain will be identical to feeding just pellets.

b. If you have been feeding whole grain since at least 3 weeks of age and have increased the level of whole grain by 20% or more compared to 6 to 10 week of age, then use the relative performance corresponding to 6 to 10 weeks of age.

c. If you started whole grain feeding at 6 weeks of age and have not increased the level of whole grain by 20% or more compared to 6 to 10 weeks of age, use the relative performance corresponding to 6 to 10 weeks of age.

d. If you started whole grain feeding at 6 weeks of age and have increased the level of whole grain by 20% or more compared to 6 to 10 weeks of age, use the relative performance corresponding to 0 to 6 weeks of age.

Relative Body Weight Gain $_{10 \text{ weeks to market}}$ = _____ %
Relative Feed:Gain $_{10 \text{ weeks to market}}$ = _____ %

Step 15. Calculate the body weight gain and feed/kg shipped from 10 weeks to market age:

Adjusted Body Weight Gain $_{10 \text{ weeks to market}}$
= Body Weight Gain $_{10 \text{ weeks to market}}$ * (Relative Body Weight% / 100%) = _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped $_{10 \text{ weeks to market}}$
= Feed/kg shipped $_{10 \text{ weeks to market}}$ * (Relative Feed:Gain% / 100%) = _____ * (_____ / 100%) = _____

Step 16. Calculate the cumulative body weight and feed/kg shipped for the flock:

Adjusted Market Body Weight

= Adj. Body Weight $_{6\ weeks}$ + Adj. Body Weight Gain $_{6\ to\ 10\ weeks}$ + Adj. Body Weight Gain $_{10\ weeks\ to\ Market}$

= _____ + _____ + _____ = _____

Adjusted Cumulative Feed/kg shipped $_{0\ weeks\ to\ market}$

= Adj. Feed/kg shipped $_{0\ to\ 6\ weeks}$ + Adj. Feed/kg shipped $_{6\ to\ 10\ weeks}$ + Adj. Feed/kg shipped $_{10\ week\ to\ market}$

= _____ + _____ + _____ = _____

Table 13. Weight Gain and Feed Conversion of Turkeys Fed Whole Grain Relative to Turkeys Fed Just Crumbles/Pellets

Cumulative Whole Grain %	Relative Body Weight Gain				Relative Feed:Gain		
	0 to 6 Weeks		6 to 10 Weeks	10 weeks to market	0 to 6 weeks	6 to 10 weeks	10 weeks to market
	Whole Wheat	Whole Barley	Whole Wheat and Barley		Whole Wheat and Barley		
0%	100.0	100.0	100.0	100.0	100.0	100.00	100.0
5%	99.9	98.3	99.9	100.0	100.3	100.2	100.0
10%	99.8	96.5	99.9	100.0	100.6	100.3	100.0
15%	99.5	96.0	99.8	100.0	100.9	100.5	100.0
20%	99.3	95.5	99.7	100.0	101.2	100.6	100.0
25%	99.0	95.0	99.5	100.0	101.5	100.8	100.0
30%	98.7	94.5	99.4	100.0	101.8	100.9	100.0
35%	98.3	94.0	99.2	100.0	102.1	101.1	100.0
40%	97.9	93.5	99.0	100.0	102.4	101.2	100.0
45%	97.3	93.0	98.2	100.0	102.7	101.4	100.0
50%	96.7	92.5	98.4	100.0	103.0	101.5	100.0
55%	96.1	92.0	98.1	100.0	103.5	101.8	100.0

Example 2: Delayed Feeding of Whole Wheat to Turkeys

Step 1. Collect the following information for typical performance for the producer and feed mill that you are dealing with for diets containing no whole grain:

a. Feed consumed per kg shipped:

Pre-Starter: _____ Starter: _____ Grower 1: _____ Grower 2: _____ Finisher: _____

b. Body Weight, kg:

6 weeks old: _____ 10 weeks old: _____ Market age: _____

Step 2. Decide how much whole grain you want in each ration in the first 6 weeks.

Step 3. Calculate the cumulative whole grain intake in the first 6 weeks based on the levels of whole grain that will be fed.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
PreStart	_____	* _____/100%	= _____
Starter	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100%
= _____ %

Step 4. Using Table 13 on page 18, look up the relative gain and feed:gain corresponding to the cumulative level of whole grain that you plan to use in the first 6 weeks.

Relative Body Weight Gain = _____ %
Relative Feed:Gain = _____ %

Step 5: Calculate the expected body weight and feed efficiency at 6 weeks of age for the whole feeding program chosen:

Adjusted Body Weight $_{6\ weeks}$
= Body Weight $_{6\ weeks}$ * (Relative Body Weight $_{6\ weeks}$/100%)
= _____ * (_____ / 100%) = _____
Adjusted Feed/kg shipped $_{0\ to\ 6\ weeks}$
= Feed/kg shipped $_{0\ to\ 6\ weeks}$ * (Relative Feed:Gain / 100%)
= _____ * (_____ / 100%) = _____

Step 6. Decide how much whole grain you want in each ration from 6 to 10 weeks of age.

Step 7. Calculate the cumulative whole grain from 6 to 10 weeks of age.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100% = _____ %

Step 8. Calculate typical body weight gain on pellets without whole grain from 6 to 10 weeks

Body Weight Gain $_{6\ to\ 10\ weeks}$
= Body Weight $_{10\ weeks}$ - Body Weight $_{6\ weeks}$
= _____ - _____ = _____

Step 9. In this example, you increased whole wheat usage by more than 20% from 6 to 10 weeks compared to 0 to 6 weeks, e.g. increasing from an average of 4% to 26%. Because of this large increase, select from the table on page 18, the relative performance corresponding to 26% whole grain from 0 to 6 weeks of age and use it to estimate the relative performance at 6 to 10 weeks of age.

Relative Body Weight Gain $_{6\ to\ 10\ weeks}$ = _____ %
Relative Feed:Gain $_{6\ to\ 10\ weeks}$ = _____ %

Step 10. Calculate the body weight gain, feed/kg shipped, and from 6 to 10 weeks of age:

Adjusted Body Weight Gain
= Body Weight Gain $_{6 \text{ to } 10 \text{ weeks}}$ * (Relative Body Weight% / 100%) = _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$
= Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$ * (Relative Feed:Gain% / 100%) = _____ * (_____ / 100%) = _____

Step 11. Decide how much whole grain that you want to feed in each diet from 10 weeks of age to market.

Step 12. Calculate the cumulative whole grain intake from 10 weeks of age to market.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Finisher	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ = _____

Step 13.

Calculate typical body weight gain on pellets without whole grain from 10 weeks to market age:

Body Weight Gain $_{10 \text{ weeks to market}}$
= Body Weight $_{\text{market}}$ - Body Weight $_{10 \text{ weeks}}$
= _____ - _____ = _____

Step 14. From the table on page 18, find the relative performance from 10 weeks of age to market corresponding to the average level of whole grain calculated in Step 14. Because you have been feeding whole grain since at least 3 weeks of age and have increased the level of whole grain by 20% or more compared to 6 to 10 week of age, use the relative performance corresponding to 6 to 10 weeks of age.

Relative Body Weight Gain $_{10 \text{ weeks to market}}$ = _____ %
Relative Feed:Gain $_{10 \text{ weeks to market}}$ = _____ %

Step 15. Calculate the body weight gain and feed/kg shipped from 10 weeks to market age:

Adjusted Body Weight Gain $_{10 \text{ weeks to market}}$
= Body Weight Gain $_{10 \text{ weeks to market}}$ * (Relative Body Weight% / 100%) = _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped $_{10 \text{ weeks to market}}$
= Feed/kg shipped $_{10 \text{ weeks to market}}$ * (Relative Feed:Gain% / 100%) = _____ * (_____ / 100%) = _____

Step 16. Calculate the cumulative body weight and feed/kg shipped for the flock:

Adjusted Market Body Weight
= Adj. Body Weight $_{6 \text{ weeks}}$ + Adj. Body Weight Gain $_{6 \text{ to } 10 \text{ weeks}}$ + Adj. Body Weight Gain $_{10 \text{ weeks to Market}}$
= _____ + _____ + _____ = _____

Adjusted Cumulative Feed/kg shipped $_{0 \text{ weeks to market}}$
= Adj. Feed/kg shipped $_{0 \text{ to } 6 \text{ weeks}}$ + Adj. Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$ + Adj. Feed/kg shipped $_{10 \text{ week to market}}$
= _____ + _____ + _____ = _____

Example 3: Early Feeding of Whole Wheat to Turkey Flocks

Step 1. Collect the following information for typical performance for the producer and feed mill that you are dealing with for diets containing no whole grain:

a. Feed consumed per kg shipped:

Pre-Starter: _____ Starter: _____ Grower 1: _____ Grower 2: _____ Finisher: _____

b. Body Weight, kg:

6 weeks old: _____ 10 weeks old: _____ Market age: _____

Step 2. Decide how much whole grain you want in each ration in the first 6 weeks.

Step 3. Calculate the cumulative whole grain intake in the first 6 weeks based on the levels of whole grain that will be fed.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
PreStart	_____	* _____/100%	= _____
Starter	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100%
= _____ %

Step 4. Using Table 13 on page 18, look up the relative gain and feed:gain corresponding to the cumulative level of whole grain that you plan to use in the first 6 weeks.

Relative Body Weight Gain = _____ %
Relative Feed:Gain = _____ %

Step 5: Calculate the expected body weight and feed efficiency at 6 weeks of age for the whole feeding program chosen:

Adjusted Body Weight $_{6\ weeks}$
= Body Weight $_{6\ weeks}$ * (Relative Body Weight $_{6\ weeks}$/100%)
= _____ * (_____ / 100%) = _____
Adjusted Feed/kg shipped $_{0\ to\ 6\ weeks}$
= Feed/kg shipped $_{0\ to\ 6\ weeks}$ * (Relative Feed:Gain / 100%)
= _____ * (_____ / 100%) = _____

Step 6. Decide how much whole grain you want in each ration from 6 to 10 weeks of age.

Step 7. Calculate the cumulative whole grain from 6 to 10 weeks of age.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ * 100% = _____ %

Step 8. Calculate typical body weight gain on pellets without whole grain from 6 to 10 weeks

Body Weight Gain $_{6\ to\ 10\ weeks}$
= Body Weight $_{10\ weeks}$ - Body Weight $_{6\ weeks}$
= _____ - _____ = _____

Step 9. From the table on page 18, find the relative performance corresponding to the average level of whole grain calculated in Step 6. Since in this example you increased whole grain usage by less than 20% from 6 to 10 weeks compared to 0 to 6 weeks, e.g. from 4% to 18%, use the relative performance expected at 6 to 10 weeks of age.

Relative Body Weight Gain $_{6\ to\ 10\ weeks}$ = _____ %
Relative Feed:Gain $_{6\ to\ 10\ weeks}$ = _____ %

Step 10. Calculate the body weight gain, feed/kg shipped, and from 6 to 10 weeks of age:

Adjusted Body Weight Gain
= Body Weight Gain $_{6 \text{ to } 10 \text{ weeks}}$ * (Relative Body Weight% / 100%) = _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$
= Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$ * (Relative Feed:Gain% / 100%) = _____ * (_____ / 100%) = _____

Step 11. Decide how much whole grain that you want to feed in each diet from 10 weeks of age to market.

Step 12. Calculate the cumulative whole grain intake from 10 weeks of age to market.

Diet	Feed Intake kg/kg shipped	% whole grain to be used	kg whole grain/kg shipped
Grower	_____	* _____/100%	= _____
Grower	_____	* _____/100%	= _____
Finisher	_____	* _____/100%	= _____
Total	_____		_____

Cumulative Whole Grain
= (total whole grain/kg) / (total feed/kg) * 100%
= _____ / _____ = _____

Step 13.

Calculate typical body weight gain on pellets without whole grain from 10 weeks to market age:

Body Weight Gain $_{10 \text{ weeks to market}}$
= Body Weight $_{\text{market}}$ - Body Weight $_{10 \text{ weeks}}$
= _____ - _____ = _____

Step 14. From the table on page 18, find the relative performance from 10 weeks of age to market corresponding to the average level of whole grain calculated in Step 14. Because you have been feeding whole grain since at least 3 weeks of age and have increased the level of whole grain by 20% or more compared to 6 to 10 week of age, use the relative performance corresponding to 6 to 10 weeks of age.

Relative Body Weight Gain $_{10 \text{ weeks to market}}$ = _____ %
Relative Feed:Gain $_{10 \text{ weeks to market}}$ = _____ %

Step 15. Calculate the body weight gain and feed/kg shipped from 10 weeks to market age:

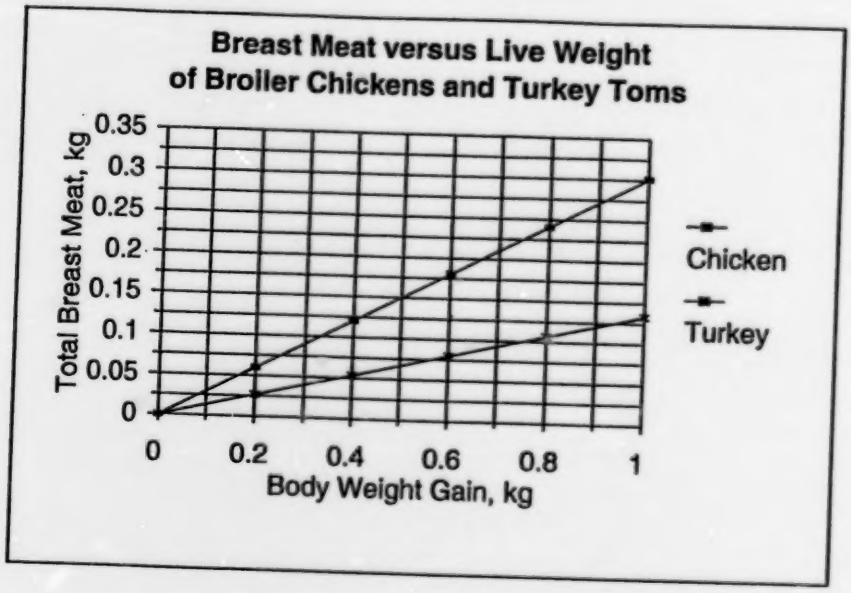
Adjusted Body Weight Gain $_{10 \text{ weeks to market}}$
= Body Weight Gain $_{10 \text{ weeks to market}}$ * (Relative Body Weight% / 100%) = _____ * (_____ / 100%) = _____

Adjusted Feed/kg shipped $_{10 \text{ weeks to market}}$
= Feed/kg shipped $_{10 \text{ weeks to market}}$ * (Relative Feed:Gain% / 100%) = _____ * (_____ / 100%) = _____

Step 16. Calculate the cumulative body weight and feed/kg shipped for the flock:

Adjusted Market Body Weight
= Adj. Body Weight $_{6 \text{ weeks}}$ + Adj. Body Weight Gain $_{6 \text{ to } 10 \text{ weeks}}$ + Adj. Body Weight Gain $_{10 \text{ weeks to Market}}$
= _____ + _____ + _____ = _____

Adjusted Cumulative Feed/kg shipped $_{0 \text{ weeks to market}}$
= Adj. Feed/kg shipped $_{0 \text{ to } 6 \text{ weeks}}$ + Adj. Feed/kg shipped $_{6 \text{ to } 10 \text{ weeks}}$ + Adj. Feed/kg shipped $_{10 \text{ week to market}}$
= _____ + _____ + _____ = _____



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Dilution Notes

- Turkeys breast meat and live wt responded to synthetic aa and chickens did not.
- Extra aa to allow very high levels of wheat not economical for turkeys or chickens.
- Turkeys and leghorns least suited to dilution but best suited for whole grain. Opposite for broiler chickens.
- Can review other research using pelleted or mash diets since formulation response not affected by feed form.
- Chicken broiler male quicker to drop live wt and breast meat as lower aa in diet than female.
- If you ignore effect on breast meat, there may be some economic benefit to diluting broiler diets.
- Carcass yield only slightly affect in chicken, possibly due to larger fat pad (maybe 0.2%). Turkey yield greatly affected. The difference is that % breast meat in turkeys, but not chickens, is strongly related to live body weight.
- Unless diets have significantly more aa and cp than NRC, 1994, do not dilute.
- Potential benefit to producers in formulating low protein diets is modest for broiler chickens, perhaps 1 cent/kg shipped while potential loss to turkey growers is significant (perhaps 3 cents/kg shipped).
- Turkeys responded positively to extra synthetic aa's but chickens did not.
- On the chicken, in my 2 trial average (but based on breast yield from only one trial), you lose about 0.5% breast yield on carcass (0.4% actual in 1 trial) or 0.33% on live wt. You lose 2.5% on live wt, 0.2% yield. Assume 75 g daily gain at end of flock (81 g actual in 2 trials).

1.900 kg bird * 0.65 yield * 0.21 breast yield = 0.259 kg breast meat
1.900 kg bird * 0.648 yield * 0.205 breast yield = 0.252 kg breast meat
----> Or de-bone 2.75% more birds @ 1.90 kg/bird and market 2/3's day later
1.953 kg bird * 0.648 yield * 0.205 breast yield = 0.259 kg breast meat
----> No need to de-bone more birds but market birds 1 1/3 days later
1.900 kgg bird * 0.975 live wt * 0.648 yield * 0.205 breast yield = 0.246 kg breast meat
—> Or de-bone 5.3% more birds @ 1.853 kg/bird with no change in market age

- Marketing dep't must look at above range of live wt and results parts etc to say if good or bad (Each option affects # and size breasts, legs, drums, whole birds). Feed mill must present range of diets and effect on live weight and estimate of growing to different live wt. Plant must provide breast yield for different diets plus a labour/plant cost of de-boning more or less birds.
- If dilute a grower instead of feeding a finisher, it is simply a formulation question: Compare specs of finisher and diluted grower. If cp and aa's same then likely no difference. Rule of thumb: need 30 to 40% dilution of starter to get to same lysine as finisher.
- Plants can track % of runts if in-line bird weighing and all plants can cut open drumsticks for TD as well as track % trim.

Table 2. Body Weight Gain of Chickens and Turkeys Fed Different Levels of Whole Grain Compared to 100% Pellets[1] (First 6 Weeks of Whole Grain Feeding)

Whole Grain[2], %	Whole Wheat	Whole Barley	Turkeys	Chickens
0 %	100.0 %	100.0%	100.0 %	100.0 %
5 %	98.9 %	98.4 %	97.4 %	99.5 %
20 %	99.5 %	98.1 %	98.9 %	99.0 %
35 %	97.0 %	93.2 %	88.7 %	96.9 %
50 %	97.0 %	94.7 %	92.7 %	96.8 %
65 %	95.6 %	94.0 %	----	94.8 %

Relative Gain = 99.72% - 0.09% * Whole Grain %

[1] Results treatments with just pellets or pelleted supplements. All results expressed as a percentage of treatments with no whole grain. The results are based on 2 chicken and 2 turkey whole wheat feeding trials and 1 chicken and 1 turkey whole barley feeding trial.
[2] Performance based on time period when a given level of whole grain was fed.

Table 3. Feed:Gain of Chickens and Turkeys Fed Different Levels of Whole Grain[1] Relative to 100% Pellets[2] (First 6 Weeks of Whole Grain Feeding)

Whole Grain,%	Feed:Gain[3]
0%	100.0 %
5%	100.9 %
20%	102.3 %
35%	102.5 %
50%	103.6 %
65%	104.3 %

Relative Feed:Gain = 100.389% + 0.065% * Whole Grain %

[1] Average results from wheat and barley mash trials
[2] Performance based on time period when a given level of whole grain was fed.
[3] A relative feed:gain > 100% is less efficient than pellets.

Body Weight, Feed Efficiency, Carcass Yield and Feed+Chick Cost of Broilers Fed Two Different Levels of Lysine[1]						
	Male		Female		Average	
	Control[2]	Low Lysine[3]	Control[2]	Low Lysine[3]	Control[2]	Low Lysine[3]
Body Weight Gain, kg (2 to 6 weeks of age)						
Trial 1	2.252	2.178	1.932	1.899	2.092	2.038
Trial 2	2.187	2.105	1.789	1.77	1.987	1.937
Average	2.220	2.142	1.861	1.835	2.040	1.988
Feed:Gain (2 to 6 weeks of age)						
Trial 1	1.749	1.857	1.87	1.885	1.81	1.871
Trial 2	1.893	1.954	1.997	2.047	1.945	2.001
Average	1.821	1.906	1.934	1.966	1.878	1.936
Carcass Yield (% of live weight)						
Trial 1	63.5	62.8	62.3	62.5	62.9	62.7
Trial 2	62.1	61.4	61.6	61.9	61.9	61.7
Average	62.8	62.1	62.0	62.2	62.4	62.2
Feed + Chick Cost, cents/kg shipped[4]						
Trial 1	79.1	78.1	81.8	79.8	80.5	79.0
Trial 2	78.9	79.3	84.5	82.5	81.7	80.9
Average	1.8	1.9	1.9	2.0	1.9	1.9
Cost of Finisher, $/tonne						
Trial 1	253.8	236.7	253.8	236.7	253.8	236.7
Trial 2	264.2	247.0	264.2	247.0	264.2	247.0
Average	259.0	241.8	259.0	241.8	259.0	241.8
Feed:Gain, uncorrected, for Finisher						
Trial 1	2.308	2.277	2.335	2.299	2.322	2.288
Trial 2	2.240	2.358	2.355	2.391	2.297	2.374
Average	2.274	2.318	2.345	2.345	2.310	2.331

[1]The low lysine diets were created by diluting the soybean and meat in the ration with wheat
[2]Lysine content in control rations= 1.05% in grower, 0.95% in finisher
[3]Lysine content in low lysine rations = 0.90% in grower, 0.80% in finisher
[4]The ingredient costs for both trials based on averages in Saskatoon for Sept.'95 to Aug.'97

Options for rearing birds on control and diluted diets to get same tonnes of breast meat from flock:

= 1.900 kg bird * 65.0% carcass yield * 21.0% breast meat yield = 0.259 kg breast meat/bd

= 1.853 kg bird * 64.8% carcass yield * 20.6% breast meat yield = 0.247 kg breast meat/bd.
----> Need to debone 5% more chickens to obtain the same tonnes of breast meat/flock

= 1.900 kg bird * 64.8% carcass yield * 20.6% breast meat yield = 0.253 kg breast meat/bd.
—> Need to debone 2% more chickens to obtain the same tonnes of breast meat/flock

= 1.940 kg bird * 64.8% carcass yield * 20.6% breast meat yield = 0.259 kg breast meat/bd.
-----> Debone same number of birds as on control rations